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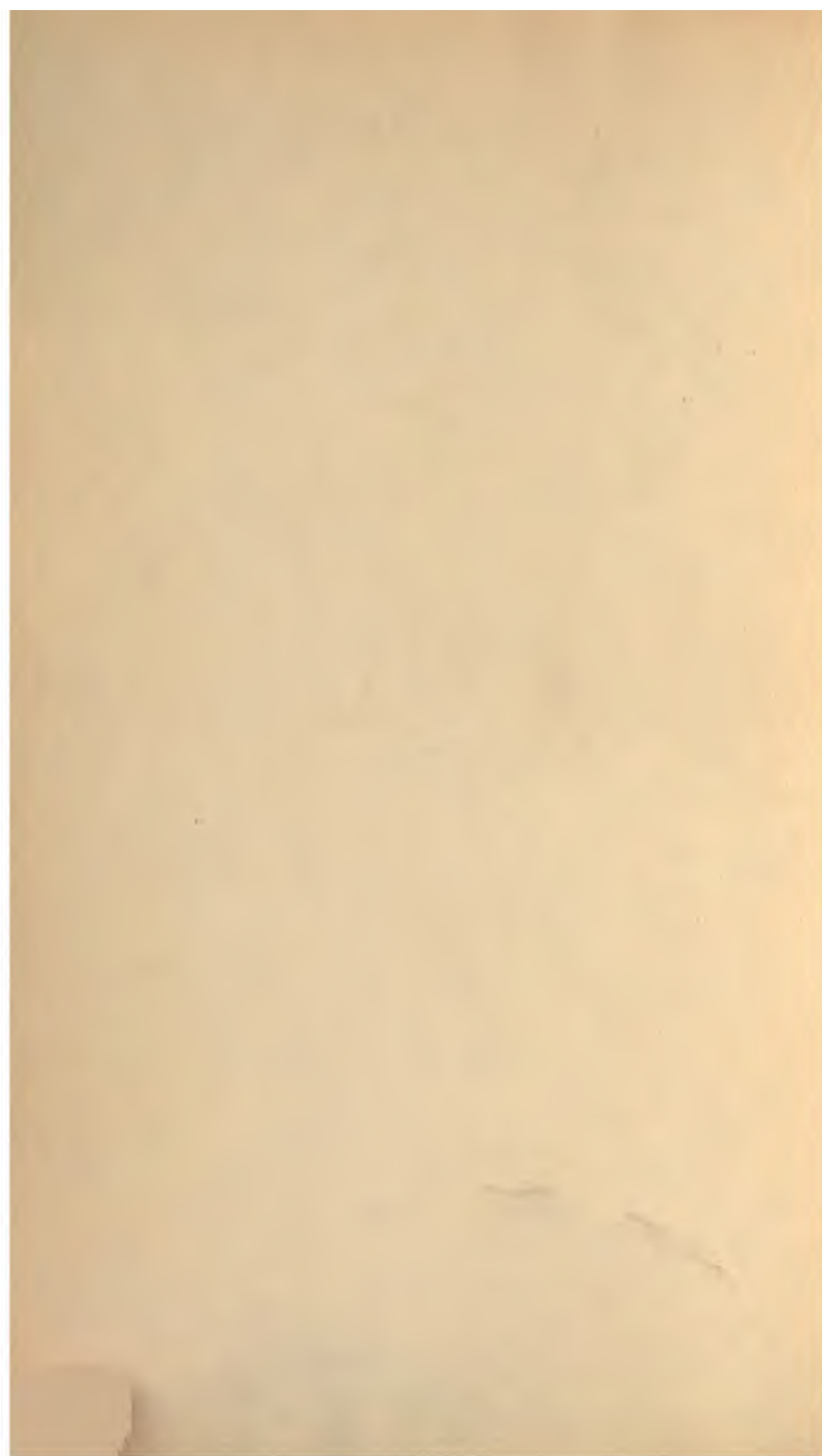
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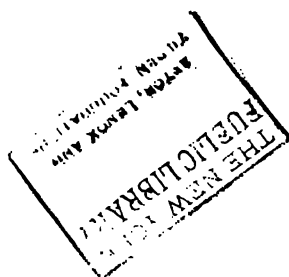






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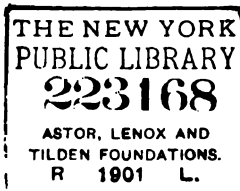
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FOR REVIEW.

[See *Publications A. S. P.*, Vol. VIII, p. 101.]

The Call, San Francisco, California.
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The Times, Los Angeles, California.
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IS MARS'S AXIAL VELOCITY CHANGING?

BY A. M. MATTOON.

The main principles of the Nebular Hypothesis were published about a century ago. LAPLACE reasoned skillfully regarding the behavior of a contracting mass, such as that of which he believed the solar system to have been composed. He described the processes by which successive concentric rings would become detached from the central body of gas, and the material ultimately be gathered together to form the planets. The equatorial telescope has done little or nothing to confound the argument of the great astronomer. *Saturn's* rings may be deemed incompetent witnesses to sustain his theory, on the grounds that they consist of countless myriads of minute moons, already solidified, and are no longer in the nebulous state. But surely *Andromeda* affords an object-lesson not liable to this criticism. Here on gigantic scale we have *Saturn* reproduced — this time in the very material considered by the noted Frenchman.

But some will, no doubt, maintain that processes different from the ring formation may have brought a planet out of chaos. JACOBI and POINCARÉ and the younger DARWIN have told us of the probability of a different order of events. They have argued that a rotating nebula may readily become a prolate spheroid, the axis of whose motion is its shortest diameter. They have reasoned that with increase of speed this ellipsoid must *necessarily* change its form into that of a pear-shaped body, called the apoid, and this in turn modify its outline till it becomes a huge dumb-bell, in which the globes are widely discrepant in size. According to a law of physics, a line drawn on the surface from one pole of a rotating body to the other, will describe equal areas in equal times, provided the body is unobstructed in its axial motion. Then, if condensation of the nebula result in contraction, *as it must*, the increase of speed would ultimately produce so heavy a strain upon the slender neck uniting the two balls as to sunder it; and thus a world would set up its independence from the Sun, though still yielding him a loyal allegiance in becoming his faithful attendant.

We shall have no occasion to quarrel with any of these eminent scientific men regarding the history of the bodies composing the

solar system, and the manner of their building. Both may be right, for aught we need to know in dealing with our present question. It is certain that planets abound; and the remarkable harmony which they display regarding the direction of their axial motion at least suggests that once there was some sort of physical connection. Prophecy is not the province of this paper; hence no prediction is ventured concerning what the future will disclose with reference to the rotation of *Uranus* and *Neptune*. At least six planets, as well as the central luminary of the solar system, turn on their axes in the same direction.

But what about the uniformity of the *rate of rotation* these bodies have continued to maintain? Have any of them changed their axial velocities? According to a law already quoted, if they have contracted, that would cause their rotation to become *increasingly* rapid. But is there some mysterious brake, somewhere in space, that can operate to *diminish* the speed of motion on the axis? It is hardly possible that *Mercury* and *Venus* should not once in the ages of antiquity have been turning faster than at present. How is it that now they are keeping the same face toward the Sun? YOUNG, in his "General Astronomy," has said regarding the rotation of *Jupiter*: "The great red spot has given values ranging from $9^h 55^m 34^s.9$ (in 1879) to $9^h 55^m 40^s.7$ (in 1886), the time of rotation as determined in each case being certainly accurate within half a second." If the Princeton astronomer is right, here is a lengthening of the day by nearly six seconds in seven years.* This is a question of *fact*, and not of *theory*; and its answer is within the reach of the telescopes of the present day. Has the Sphinx propounded another riddle? The friction of the tides may be suggested as a possible explanation. But what about the neutralizing influence upon the tides, when satellites are scattered about profusely? The query naturally arises, whether it is possible that *Jupiter's* axial motion will ever diminish, so that the nearest satellite will revolve in a period shorter than that of the planet's rotation. If so, we shall then have the behavior of *Mars* and *Phobos* duplicated. In such a case Mr. DARWIN's theory of tidal evolution may need some modifications to adapt it to the case in hand. No attempt will here be made to disparage the argument of this eminent English

* It should be noted that different markings on *Jupiter*, even in the same latitude, give different values for the rotation period; and it is at least possible that all of the visible markings are in motion relatively to the planet's surface.

mathematician. No effort is to be put forth to cause any one to doubt that the tides on *Mars* may have influenced the orbital motion of *Phobos*. This discussion will pertain to a question entirely independent of that. The attempt will be made to show that *the day on Mars is gradually growing longer*.

At favorable opposition, the planet is only a little over thirty-five million miles away from us. The opportunities for advantageous observation are frequent enough for astronomers to have some idea of the surface and climates of the various portions of the globe. Enough is known of the polar caps to make it almost absurd to claim that they can be any thing else than snow or ice. They have a diameter almost identical with that of the frigid zones, and have the poles of the planet as their approximate centers. When the northern hemisphere is in a position analogous to that which upon the Earth produces summer, the arctic cap disappears, and the southern one gradually grows to its full proportions. But when half the Martian year rolls round, the northern cap becomes a prominent object, while the one about the opposite pole slowly vanishes. The planet's equator is inclined $24^{\circ} 50'$ to the plane of its orbit; hence its frigid zones are similar to those upon the Earth, except that they are a little larger in proportion to the size of the sphere upon which they are situated. The year upon that globe is a little over twenty-two months long, as we count time; hence the arctic winter must last nearly or quite eleven months. The planet is farther from the Sun than we are; and this would naturally cause the winters there to be colder and longer in proportion to the length of the year than we have them here upon the Earth.

SCHIAPARELLI's map represents *Mars* as having but one ocean of any real magnitude, and that is situated almost wholly in the southern hemisphere. During the time that the northern snow-cap is forming the Sun's most potent influence is felt just south of the equator, in that part of the ocean lying within the torrid zone. Hence the vapor that is ultimately converted into the snow that goes to form the cap, must come mainly, if not entirely, from the southern hemisphere. Now, this great volume of water is transferred to the polar regions by means of the atmosphere. Here upon the Earth the clouds that become vehicles to transport moisture between places widely separated, do not appear to affect, in the least, the Earth's axial motion. Whatever results might be produced that way, if they are worth

considering at all, must be more or less like the friction of the tides, and could hardly operate to accelerate rotation. Indeed, if tides destroy momentum, the broad currents in the great oceans of air would doubtless exert a kindred influence, rather than the opposite. However, nothing is based upon this, other than that the transfer of water from the ocean in the southern hemisphere to the northern polar regions is accomplished without appreciable alteration in the planet's period of rotation. Now, when the moisture, which came from the ocean in close proximity to the equator, left its home upon the sphere, the swiftness of the planet's motion in those regions had given it considerable momentum. Whether or not any of its energy was dissipated into space during the long journey northward, which is not at all improbable, when it settled down again upon the planet, it took up a position so much nearer the axis of the rotating sphere, that the leverage which it had, to act upon that body, was so reduced that it could not possibly restore all that it had taken away. Here in its new position its motion due to the rotation of the globe is very slow. As has been said, the Martian winter in the polar regions would doubtless be not far from eleven months long, nearly twice that of the corresponding seasons in the frigid zones upon the Earth. Accepting Mr. CAMPBELL's estimate that the atmosphere on *Mars* is not more than one fourth as dense as that to which we are accustomed, and at the same time taking into account the fact that the area covered by the water on the planet just named is only about two thirds as great in proportion to the size of the sphere as the oceanic surface of the Earth, it is certainly far within bounds *to estimate the average depth of snow* in the northern cap, when it attains its maximum, *to be two feet*.

Snow left undisturbed for so long a time as this remains in place, becomes packed extremely hard. Even when the superficial gravity is but a fraction of what it is upon the Earth, such snow would yield a large percentage of its bulk in water, when the advent of spring would cause it to melt. Experiments performed upon snow only moderately compressed show that it will yield about 40 per cent. of its bulk in water. Professor PICKERING, in the October, 1892, number of *Astronomy and Astrophysics*, states that the cap covered the polar regions down to 65° north latitude. That makes its area a zone with a radius of 25°, having the pole as its approximate center. Though the planet is really

a *spheroid*, its eccentricity is so small that, for all practical purposes, we shall admit no appreciable error in regarding the cap as covering a zone of a sphere. From geometry, such an area equals the altitude of the zone multiplied by the circumference of a great circle. Supplying the figures for a planet whose radius is 2,100 miles, we obtain as the area of the cap almost exactly 2,600,000 square miles. This area, reduced to square feet and multiplied by the estimated two feet, as the average depth of snow, gives the volume as 145 trillion* cubic feet, which would yield 58 trillion cubic feet of water. We are accustomed in our laboratory experiments to think of water as weighing $62\frac{1}{2}$ pounds to the cubic foot. But upon *Mars* surface gravity is only 38 per cent. as great as here; therefore a cubic foot of water there, weighed by our spring balances, would weigh only $23\frac{3}{4}$ pounds. *This makes the weight of the cap about $13\frac{1}{8}$ quadrillion pounds.*

The planet is an oblate ellipsoid, whose equatorial diameter is about 4,200 miles, and the polar diameter some twenty miles less. The integral calculus gives the volume of such a solid as something over $38\frac{1}{2}$ billion cubic miles, and the exact figures being reduced, make the result a little more than $5\frac{2}{3}$ sextillion cubic feet. As has already been stated, one cubic foot of water at the Earth's surface weighs $62\frac{1}{2}$ pounds. The average cubic foot of the Earth weighs 5.58 times as much, or $348\frac{3}{4}$ pounds. But the density of *Mars* being only 73 per cent., and surface gravity 0.38, one cubic foot of that planet, weighed upon its own surface, would give a result of $96\frac{3}{4}$ pounds. Multiplying this by the volume in cubic feet, we find that *Mars weighs just a little short of 550 sextillion pounds*—that is, fifty-five with twenty-two ciphers annexed.

Now, if we are to determine the influence of the snow-cap upon the planet, we must separate the weight of each from the other. But the figures last given consist of the total weight of everything on the sphere and within it. Preserving the significant figures in the exact computation down to billions, and deducting the weight of the cap from the total weight, we obtain *for the weight of the planet, exclusive of the cap, about 549½ sextillion pounds.*

According to mechanics, momentum is the product of mass

* The American and French system of notation will be employed in the figures it becomes necessary to use.

and velocity. But the velocity of *Mars* due to rotation is neither that of the swiftest particle, which is situated on the equator, nor that of one located on the axis, where the speed reduces to zero. But there must be a mean, or representative, particle, situated somewhere between these two extremes. Now, either the northern or southern hemisphere may be regarded as generated by the revolution of one fourth of an ellipse about the semi-minor axis. The mean particle in this quarter-ellipse will, of course, reside at its center of gravity. The opposite hemisphere from that treated first, would give as a result for its center of gravity a distance from the minor axis the same as the other, and the representative particle for the *whole planet* would be at the middle of the line joining the two centers of gravity just described. Thus the radius of gyration for *Mars* would have a length equal to the distance of that point from the polar axis of the planet. Summoning the integral calculus again to our assistance, we find the radius sought to be 891.2 miles. This means that during one rotation of *Mars* the representative particle describes a circle whose radius is the length just given. This it does in one Martian day, which, at present is 88,642.67 seconds long. A simple arithmetical calculation will show that its speed is 333.542 feet per second. Since momentum is the product of mass and velocity, and these two factors now are known, *the planet, exclusive of the cap, has a momentum of 1833½ septillion foot-pounds, a number consisting of twenty-seven figures.*

Now, the cap at its maximum covers a zone of one base whose radius is twenty-five degrees, the pole being the center of the same. Let two opposite meridians of the planet be conceived as drawn: then if a plane bisect the sphere in such a way as to include these two meridians, and that plane be extended so as to cut this northern snow-cap into halves, the section formed would be a crescent. The produced axis of the planet would bisect this section. One of these two half-crescents may be regarded as a triangle, two of whose sides are arcs of circles, with sides twenty-five degrees long and described by radii a little greater than the semi-major axis of the planet. The calculus shows that this radius is almost exactly 2,110 miles long. The third side of this triangle is a straight line whose length is equal to the depth of the snow at the pole. While this semi-section of the ice-cap is not a triangle in the common acceptation of that term, for our present purpose it is near enough to it for the law

about to be introduced to be applicable. According to mechanics, the representative particle in this quasi-triangle will reside on the medial line (here an arc) one third of the distance from the base to the vertex. This locates it $8^{\circ} 20'$ from the pole. The perpendicular distance of this point from the axis of the planet, according to trigonometry, is $305\frac{3}{4}$ miles. The velocity of the snow-cap due to the planet's axial motion is that of this mean particle, which in one Martian day, at the present rate, describes a circle whose radius is $305\frac{3}{4}$ miles, in 88,642.67 seconds. This makes the velocity of the cap 114.4 feet per second. The factors are now both known for finding *the momentum of the ice-cap*; and their product makes it *a little more than 157½ quadrillion foot-pounds, while the material of the cap lies in the arctic regions.*

Reference has been made to SCHIAPARELLI'S map of *Mars*. An examination of it will reveal the fact that a very large proportion of the so-called canals lead from the north polar regions directly to the ocean. Mr. LOWELL, who has given this planet special study, expresses the belief that these markings are stretches of country containing luxuriant vegetation, and that the soil is rendered productive by a central watercourse. He concludes that these channels convey the fluid product of these annually recurring snow-caps back to the ocean. Whether that explanation be the true one or not, if the vapor that becomes snow and goes to form these caps comes *from* the ocean, it must find its way back *to* it again, else it would not take many years to drain it of all its contents. As that body of water is almost wholly in the southern hemisphere, the annual flow of water from the arctic regions must cross the equator to reach the ocean. Then at the crossing-point, this melted snow attains a velocity due to axial motion equal to the swiftest particle on the planet. But it will hardly be fair to compute its momentum for *that* locality, and say that it has gained the difference between *that* and what it had while lying in the frigid zone. When the cap was in process of formation the southern hemisphere had summer; and the evaporation of water that entered into the material composing the cap took place *south* of the equator, mainly in the torrid zone. It will certainly be fair to estimate the vapor as coming from an average distance of 20° south of the equator. To preserve the equilibrium it must necessarily return to the places whence it came. Then, whatever influence this water-flow has for the twenty degrees after crossing the equator would be coun-

terbalanced by that of the last twenty degrees before that line was passed. Hence the ultimate effect would be produced at 20° north latitude. Here the radius of gyration would be 1972.2 miles. The velocity of a point upon the surface at that locality, found just as before, is—at present—738.1 feet per second. Then, the momentum of the cap, when its material is returned to its original resting-place in the ocean bed, is $1,016\frac{1}{4}$ quadrillion foot-pounds. But the momentum obtained for it before it left the frigid zone was a little over $157\frac{1}{2}$ quadrillion foot-pounds. Hence the increase in momentum was more than 858 quadrillion foot-pounds. But this gain had to be imparted to it by the planet, or what the cap gained the rest of the planet lost.

It is evident that the material composing both planet and snow-cap together is not a variable quantity—that is, the joint mass is constant. Now, since momentum is the product of mass and velocity, if the momentum suffer a decrease, the result must be a diminished velocity. To find what this factor is under the new conditions, we must divide the joint momentum by the total mass. Supplying the exact figures, and performing the indicated division, the quotient obtained is 333.54177166 feet per second. Now, this is the velocity of the mean particle which is, as before shown, 891.2 miles from the axis of rotation. When particles describe the same circle at different velocities, their times are inversely proportional to their velocities. Hence the new velocity is to the old as the old period is to the new. Substituting values, we have the proportion—

$$333.54177166 : 333.542 :: 88,642.67 : 88,642.76.$$

From this we see that the day has been lengthened by 0.09 of a second by one transfer of the material of the snow-cap from the ocean to the north pole and back again. The southern cap doubtless influences axial velocity to some extent; but the conditions under which it acts are very different from those of the northern one, and cannot be discussed here. If the northern cap produces the effect here indicated, it would require only 680,000 Martian years, or 1,275,000 of our years, to change the length of the day by 17 hours. This is equivalent to saying that so long ago the day there might have been only $7^{\text{h}} 37^{\text{m}} 22^{\text{s}}.67$ long, which is shorter than the orbital period of *Phobos*, the inner satellite of *Mars*.

The reader should not receive the impression from the preceding argument that the writer considers it established that

680,000 years ago, or even twice or thrice that period, *Mars* was rotating at any such rate of speed as indicated in the foregoing figures. That there have been, and still are, influences at work to counteract, *in part*, the effects of these spring freshets, has not escaped notice.

In the first place, as the water returns from the frigid zone and flows into the northern portion of the ocean bed, the water-level would be preserved by a sort of tide, setting in toward the south pole. And the eastward motion of this tide, due to the planet's rotation, being greater than the velocity of the antarctic regions, toward which it approaches, would tend to accelerate rotation. But it will be apparent that the next time evaporation takes place to form a second northern snow-cap the water comes from the same regions as before; and a northward flowing tide, to fill up the place of that which was evaporated, would counteract the influence of the former tide-wave.

In the second place, there is doubtless some influence exerted by the vapor, as it is suspended in the atmosphere while it is making its journey northward from the ocean bed to its place of long repose in the polar regions. The eastward impetus that rotation had given it would make its motion swifter than that of the lands beneath it as it approached the frigid zone, and a northeast wind would be the result. Though trade-winds do not seem to have any influence upon the Earth's rotation, it may be possible that the friction of this vapor-laden atmosphere would slightly accelerate the axial motion of *Mars*.

In the third place, all the writers on cosmogony agree that the planets began independent existence in a very heated condition, and gradually cooled, by the radiation of their heat. When *Mars* first experienced a snowfall at the pole, the quantity must indeed have been quite insignificant. This depth of two feet which has been employed in our estimate was not attained, till snow had been falling there perhaps a million years or more. This fact does not, of course, argue against what has been claimed. It merely goes to show that the forces that have been at work to destroy the planet's axial motion, have needed longer time to accomplish their results.

And now perchance some one may say that the material of the snow-cap does not come from the ocean, but from some other source. As to that, it must come from *somewhere*. Evaporation of water must take place where it is warm enough to cause it.

The snow cannot have come from the pole, nor from any source beneath the cap. Snow descends from the atmosphere. It cannot have come from the cap itself; for that does not exist for about half the year. It must have had its origin from some body of water nearer the equator than itself. In any such case, the argument of the foregoing computation maintains its force; for the water of which it is composed must return to the place whence it came, else the supply would soon be exhausted.

So it would appear, at least to an amateur in the study of astronomy, such as the writer frankly confesses himself to be, that, when the material of the Martian snow-cap moves *from a position near the axis of rotation to one more remote from it, momentum must be lost*. As the counteracting influences all combined are insufficient to restore what has been taken away, axial velocity must be diminished, and the day on *Mars* must be slowly but surely growing longer.

PARK COLLEGE, PARKVILLE, MO., December, 1898.

THE CONSTANT OF ATTRACTION.

BY FREDERICK H. SEARES.

In view of the confused designations of the constant of attraction as given by many writers upon theoretical astronomy, it is perhaps worth while for the benefit of students to call attention to its true significance.

NEWTON's law of attraction states a proportionality between the force of attraction exercised by two bodies, on the one hand, and the product of their masses divided by the square of the distance between them, on the other. In practice it is convenient to express this law in mathematical symbols in the form of an equation, the proportionality being converted into an equality by the introduction of a constant factor whose numerical value depends upon the numerical values employed for the fundamental units. Assuming the law of gravitation to be accurately true for all parts of space, this factor, which may be called the constant of attraction, is a true constant of the universe. Its value changes only with a change in the fundamental units.

The law of attraction therefore takes the form

$$\text{Force} = A (\text{mass}) \times (\text{acceleration}) = \frac{C (\text{mass}) \times (\text{mass})}{(\text{distance})^2} \quad (1)$$

where C is the constant under consideration, and A is a numerical quantity, usually unity, introduced to bring about an equality between the force and the product of the mass into the acceleration. Considered as an equation of dimensions, (1) is of the form

$$m \, l \, t^{-2} = C \, m \, m \, l^{-1} \dots \dots \dots (2)$$

from which it appears that C is of the dimensions $m^{-1} l^2 t^{-2}$, mass, length, and time being the fundamental units. It has upon occasion seemed desirable to express mass as a derived unit of the dimensions $l^3 t^{-2}$, in which case C is an abstract number. With the introduction of this new conception of mass it is to be noted that either A must be thought of as a dimensional quantity or a new conception of force must be adopted. With the usual conception of mass, C is a dimensional quantity of the form $l^3 t^{-2}$; with the new conception it is an abstract number; it is never a force or an acceleration, as is frequently stated, for it has the dimensions of neither of these quantities, although under certain circumstances it may become *numerically equal* to them. For example, if in (1) the masses and the distance are all unity, then C , the force, and the acceleration are all numerically equal. It is on account of this fact that confusion has arisen; and simple as the matter is, it is often something of a puzzle to the student who has arrived at this point in his advance.

The constant of attraction appears in two different classes of problems. First, in problems involving the relative motions of the members of the solar system. It is then called the Gaussian constant of planetary motion, and is denoted by the symbol k^2 . Secondly, it appears in problems involving the forces, accelerations, etc., due to gravitation and weight, in small masses on or near the surface of the earth. In this connection, it is called the constant of gravitation, and is usually designated by the symbols k or G . The principle involved in the use of the constant is precisely the same in the two cases; the only difference is one of numerical value.

The theory of elliptical motion leads to the equation

$$k = \frac{2 \pi a^{\frac{3}{2}}}{T \sqrt{M + m}} \dots \dots \dots (3)$$

where M and m are the two attracting masses, a their mean distance, and T the period of revolution about their common center of gravity. This equation, combined with observations upon members of the solar system, gives the numerical value of the

Gaussian constant of planetary motion. As originally defined by GAUSS, its value depended upon the mass of the Sun as the unit of mass, the mean solar day as the unit of time, and the mean distance of the Earth from the Sun as the unit of distance. Since the original evaluation of the quantity by GAUSS, more accurate values have been obtained for both the mass of the Earth and its period of revolution about the Sun, and in the future doubtless still more accurate values will be found for these quantities. It is evident that if we are to adhere strictly to the best determinations of these quantities that changes must be made from time to time in k^2 . But extensive tables have been computed with the original value of the constant, and any change in its value would lead to much inconvenience. It has seemed best, therefore, to retain unchanged the value of k^2 as given by GAUSS, and to vary the unit of distance as occasion demands, so that upon the introduction into (3) of improved values of m and T , the equation is still satisfied.

The value to be used for k is therefore

$$k = 0.017\ 202\ 098\ 95; \text{ or, } \log k = 8.235\ 581\ 441\ 4 - 10$$

and using

$$T = 365.256\ 357\ 4 \quad m = 1:330\ 000$$

the resulting value of a is given by

$$\log a = 0.000\ 000\ 009\ 9$$

from which it follows that the corresponding unit of distance is 0.999 999 977 2 of the mean distance of the Earth from the Sun.

In this connection, see GAUSS's *Theoria Motus*, First Book, First Section; also, v. OPPOLZER's *Lehrbuch zur Bahnbestimmung der Kometen und Planeten*, Vol. I, p. 48.

The value of the constant as it appears in the second class of problems, depends ordinarily upon the centimeter-gram-second system of units. It is possible to determine this value directly from equation (3); it can also be obtained from the value of the GAUSSIAN constant by multiplying by the number which will make the transfer from the one system of units to the other; but a much more accurate method is afforded by equation (1) when applied to the results of experiments for the determination of the mass and mean density of the Earth. In this case we must measure the force expressed by $G \frac{m m_1}{d^2}$, the masses m and m_1 , and the distance d being known. They may be the mountain and

the plumb-bob, as in the experiment of MASKELYN, or the surface strata of the Earth and the plumb-bob, as in the experiment of AIRY, or two spheres of known mass, as in all the various forms of the CAVENDISH experiment. It may be remarked that the gravitation constant being known, the mean density of the Earth follows from the equation

$$G \frac{V \delta m_1}{R^2} = \text{weight of } m_1 = m_1 g$$

or,

$$\delta = \frac{g R^2}{G V}$$

where R and V are the radius and volume respectively of the Earth, and g the acceleration due to gravity. It is not necessary, however, that G be known in order to determine δ , for the experiment may be so varied as to eliminate G from the problem. The result of the most recent determination, that of FATHER BRAUN, is

$$G = 0.000\ 000\ 066\ 552\ 13$$

To recapitulate: The Gaussian constant, k^2 , and the gravitation constant, k or G , are to be interpreted physically in exactly the same way; neither is ever force, mass, or acceleration; both are dimensional quantities of the form $m^{-1} l^3 t^{-2}$, when, as is usual, mass, length, and time are the fundamental units. If mass be thought of as a derived unit of dimensions $l^3 t^{-2}$, the constants are abstract numbers; but in any case their office is to convert into an equality the proportionality expressed by NEWTON'S law, and their only difference, which is a numerical one, arises from the difference in the system of units in the two classes of problems in which these constants occur.

The following are references to some of the more important papers treating of the determination of the mass and mean density of the Earth and the gravitation constant:—

- v. JOLLY. *Abhandlungen d. 2. Kl. der Münch. Akad.* XIII. 1. Abth. S. 155–176. 1878: *Ann. d. Phys. u. Chem.* Neue Folge. XIV. S. 331–355. 1881: *Münch. Akad.* XIV. 2. Abth. S. 1–26. 1883.
Wiedemann's Ann. Bd. 5, S. 112: Bd. 14, S. 331.
 POYNTING. *Proc. of the Royal Society of London*, XXVIII, p. 2, 1878.
Philosophical Transactions, vol. 182, p. 556.

Mean Density of the Earth; which is the Adams prize essay for 1893. GRIFFIN: London, 1894.

WILSING. *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, Nr. 22.

BOYS. *Philosophical Transactions*, vol. 186.

BRAUN. *Denkschriften der Kaiserlichen Akad. zu Wien*, Bd. 64.

Popular accounts and reviews of some of the above methods are to be found in

Nature, vol. 50, pp. 330, 366, 417; vol. 56, p. 127.

Himmel und Erde, Bd. X, p. 385.

Vierteljahrsschrift der Astronomischen Gesellschaft, Bd. 24, p. 18.

POYNTING's prize essay contains a valuable historical account of the subject:

ASTRONOMICAL OBSERVATIONS IN 1898.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z Cygni.*

January	10: Z = a.	September	10: $\begin{cases} > a. \\ < A. \dagger \end{cases}$
	11: id.		22: id.
	22: id.	October	3: id.
	27: $\begin{cases} < a. \\ > b. \end{cases}$		6: almost = A.
	29: id.		9: < A.
February	19: = c.		26: = a.
April	14: invisible.	November	1: $\begin{cases} < a. \\ > b. \end{cases}$
	26: id.		4: = b.
May	7: id.		6: id.
August	14: = a.		22: $\begin{cases} < d. \\ > e. \end{cases}$
	18: a little > a.	December	3: < e.
	21: id.		13: id.
	24: > a.		18: id.
September	5: much > a.		

* Vide the sketch in the *Publications* A. S. P., No. 48, page 69.

† The position of A (7. Magn.) referred to 26 *Cygni* is: $\Delta \alpha = + 1^m 52^s$

$\Delta \delta = + 12'.1$

*X² Cygni and the Stars A and B near it.**

May	7:	$\begin{cases} X^2 < A \text{ a little} \\ >_a B. \end{cases}$		
August	14:	$\begin{cases} <_g A < B. \\ >_h \end{cases}$	October	3: $< k, A \leq B.$
August	18:	id.		6: id.
	21:	$= h, A < B.$		9: id., $A < B.$
	24:	id.		14: id.
September	5:	id.		26: $\begin{cases} \text{invisible.} \\ A \bar{=} B. \end{cases}$
	7:	id.	November	1: $A \bar{=} B.$
	10:	id.		6: $A < B.$
	15:	$< h, A = B.$		22: $A = B.$
	17:	$< h, A < B.$	December	3: id.
	22:	id.		13: $A \bar{=} B.$
	23:	id.		20: $A > B.$

S Ursæ Majoris.

January	10:	S invisible.	September	10:	$= g.$
	21:	id.		15:	$= f.$
	27:	id.		17:	$\begin{cases} > f. \\ < e. \end{cases}$
February	19:	$\begin{cases} > e. \\ < d. \end{cases}$		22:	$= e.$
March	15:	$= e.$		23:	id.
	19:	a little $< d.$		25:	id.
	21:	id.		27:	id.
	23:	$= d.$		30:	id.
April	1:	id.	October	3:	$= d.$
	3:	a little $> d.$		6:	id.
	7:	$> d.$		9:	id.
	13:	$\begin{cases} > d. \\ < c. \end{cases}$	October	14:	id.
	26:	id.		25:	id.
May	7:	id.	November	1:	$> d.$
	19:	$= d.$		4:	id.
July	21:	invisible.		6:	id.
August	14:	$< g.$		22:	$\begin{cases} > d. \\ < c. \end{cases}$
	18:	id.	December	3:	a little $> d.$
	24:	id.		13:	$= d.$
September	5:	a little $> f.$		18:	a little $< d.$
	7:	$= f.$		20:	id.

* *Vide* the sketch in *Publications A. S. P.*, No. 34, page 37, and the observations in No. 48, page 71.

T Ursæ Majoris.

January	10: T = c.	September	10: > e.
	21: = a.		15: = c.
	27: a little < a.		17: id.
February	19: id.		22: { > b. < a.
March	15: { < c. > d.		23: id.
	19: a little > d.		25: a little > a.
	21: id.		27: > a.
	23: = d.		30: id.
April	1: { < d. > e.	October	3: { > a. = c in the re- gion about S.
	3: a little > e.		6: id.
	7: id.		9: = b (S).
	13: some > e.		14: id.
	26: a little < e.		25: id.
May	7: = g.	November	1: id.
	19: id.		4: < c (S).
July	21: invisible.		6: much > a.
August	14: id.		22: = a.
	18: id.	December	3: = b.
	24: = f.		13: = c.
September	5: a little < e.		18: a little > d.
	7: id.		20: = d.

*W Pegasi.**

January	8: W < g.	September	15: id.
	10: id.		17: < c.
	11: id.	September	22: { < c. > d.
	21: id.		23: = d.
	22: id.		25: < d.
	27: id.	October	3: = e.
August	14: { a little > c. < b.		6: = f.
	18: id.		9: id.
	21: id.		14: a little < f.
	24: id.		26: { invisible in moonlight.
September	5: a little < c.	November	1: a little < g.
	7: < c.		4: = g.
	10: a little < c.		

* *Vide* the sketch in the *Publications* A. S. P., No. 60, page 23.

November 6: id.	|	December 3: id.
22: < g.		13: id.
		18: id.

The Stars $\left\{ \begin{smallmatrix} 12 \text{ and } 13 \\ 14 \text{ " } 16 \end{smallmatrix} \right\}$ *Comæ Berenidis.*

January 22:	12 > 13 and 14 = 16.
29:	12 > 13 id.
March 23:	12 < 13 id.
April 1:	12 = 13 id.
7:	12 > 13 id.
13:	12 > 13 id.
14:	12 > 13 id.

Mira Ceti.

January 22:	<i>Mira</i> = 70 <i>Ceti</i> .	
September 12:	= α <i>Piscium</i> .	
October 3:	= α <i>Ceti</i> .	November 6: id.
6:	id.	22: = ξ^2 .
9:	id.	December 3: = ξ^1 .
14:	id.	13: = V.
November 1:	id.	18: a little > 71.
4:	$\left\{ \begin{smallmatrix} \text{a little} > \alpha \\ \text{Piscium.} \end{smallmatrix} \right.$	

The Red Star near ζ Tauri.

The star No. 144 in CHANDLER'S (No. 121 in BIRMINGHAM'S) Catalogue of red stars, mentioned in the *Publications A. S. P.*, No 61, page 72, has not in the past year shown any remarkable variations. On several dates I have looked out for this star = BD. 20°. 1083, and have compared it with its neighbor, the star BD. 20°. 1073. When the ocular-tube was screwed out until the stars appeared as pale discs, I always found the red star fainter, contrary to what was the case in preceding years.

Meteors observed from Stations in Denmark.

No.	M. European Time.	Beginning.	End.	Mag.	Note.
1	Jan. 2, 9 ^h 15 ^m P.M.	Near <i>Procyon</i>	Near <i>Regulus</i>	*	Fireball, seen at Roskilde, yellow and blue, "s.
2	31, 9 50		20° alt. N.N.E.	*	Fireball, seen at Glynegøre; violet. 2-38.
3	Aug. 11, 10 1	0 0	0 0	2	
4	21	215 + 70	228 + 52	2	
5	32	255 + 77	243 + 56	2	
6	34	14 + 53	353 + 46	2½	Train.
7	40	289 + 40	294 + 23	2	
8	43	233 + 70	236 + 61	3	
9	44	157 + 66	150 + 64	1	
10	48	288 + 40	280 + 24	1	
11	50	20 + 49	7 + 35	2	
12	56	209 + 73	214 + 52	2	
13	56	218 + 37	224 + 23	1	
14	11 4	353 + 25	7 + 40	3	
15	5	8 + 33	359 + 21	2	Train.
16	6	215 + 38	214 + 27	2½	
17	8	55 + 40	55 + 32	1	
18	11	353 + 28	342 + 20	1	Train.
19	12	256 + 22	253 + 10	3	
20	13	2 + 27	353 + 16	1	
21	17	292 + 28	288 + 9	2	
22	23	177 + 53	181 + 45	4	
23	29	258 + 89	236 + 78	3	
24	34	301 + 37	301 + 37	3	Stationary.
25	36	191 + 67	191 + 53	3	
26	37	347 + 21	341 + 15	3	
27	39	272 + 22	258 + 25	4	Slow.
28	46	331 — 2	324 — 6	3	
29	49	170 + 78	194 + 61	2	
30	58	294 + 28	283 + 13	1	
31	Aug. 11, 10 2	186 + 52	192 + 43	1	Nos. 3-30 were observed at Odder.
32	4	294 + 31	282 + 7	2	
33	32	258 + 44	228 + 19	1	Streak.
34	47	62 + 62	68 + 60	1	
35	51	68 + 57	68 + 57	1	Stationary.
36	11 0	38 + 56	21 + 55	2½	Train.
37	14	15 + 55	13 + 64	2	Streak.
38	23	38 + 41	24 + 41	1	
39	10 22	58 + 49	60 + 39	1	Nos. 31-38 were observed at Nyborg.
40	33	312 + 34	298 + 5	1	Train.
41	35	210 + 59	264 + 63	1	
42	35	325 + 51	307 + 16	1	
43	51	210 + 88	234 + 65	1	
44	53	15 + 35	356 + 33	1	Train.
45	55	314 + 15	337 + 14	2	
46	56	15 + 46	2 + 43	1	
47	58	205 + 47	206 + 32	1	
48	59	274 + 39	262 + 26	1	Train.
49	11 0	267 + 30	266 + 3	2	Train.
50	4	15 + 35	6 + 37	1	
51	8	31 + 35	23 + 31	1	
		15 + 35	10 + 25	1	Train.

No.	M. European Time.	Beginning.	End.	Mag.	Note.
52	Aug. 11, 11 ^h 11 ^m P.M.	251 + 39	251 + 19	1	
53		274 + 22	282 + 5	1	Train.
54		15 + 35	8 + 25	1	
55		272 + 59	257 + 41	1	Train.
56		280 + 80	192 + 75	2	
57		260 + 33	258 + 12	1	
58		22 + 50	7 + 47	1	Long train.
59		281 + 44	252 + 42	1	
60		352 + 46	341 + 39	1	
61		1 + 15	353 + 8	1	Train.
62		343 + 28	334 + 17	2	
63		7 + 63	349 + 57	1	
64		234 + 38	234 + 16	1	
65		359 + 67	340 + 61	2	
66		265 + 40	264 + 10	1	
67		296 + 10	284 - 8	1	Yellow.
68		316 + 10	311 - 9	2	Train.
69		38 + 52	37 + 39	1	Train.
70		22 + 40	18 + 30	2	
71		265 + 54	261 + 55	1	
72	Aug. 12, 10	333 + 7	323 + 1	3	
73		296 + 5	282 - 5	1	Train.
74		347 + 49	337 + 36	1	
75		355 + 58	340 + 49	2	
76		2 + 50	348 + 36	1	Train.
77		237 + 31	231 + 23	2	
78		232 + 35	222 + 25	1	
79		254 + 38	254 + 12	1	Train.
80		164 + 64	173 + 55	2	Nos. 39-80 observed at Fredericia.
81	Aug. 11, 10	33 + 33	31 + 28	*	Train.
82		360 + 28	357 + 25	*	
83		162 + 61	165 + 57	*	
84		292 + 46	289 + 18	*	Train.
85		185 + 70	170 + 60	*	
86		356 + 55	348 + 53	*	
87		206 + 50	202 + 45	*	
88		13 + 29	356 + 25	*	Train.
					Nos. 81-88 observed at Brandstrup.
89	Aug. 12, 10	308 + 40	294 + 5	1	
90		355 + 61	350 + 55	3	
91		339 + 61	321 + 54	2	
92		41 + 45	31 + 38	3	
93		30 + 65	12 + 66	1	Train.
94	11	359 + 48	356 + 39	3	
95		11 + 26	5 + 23	3	
96		340 + 61	312 + 55	2	
97		210 + 85	206 + 64	2	
98		315 + 29	309 + 23	2	
99		312 + 25	310 + 23	2	
100		354 + 32	347 + 25	3	
101		344 + 34	339 + 26	2	
102	12	21 + 41	29 + 37	3	Nos. 89-102 observed at Ulkeböl.
103	Aug. 15, 9	128 + 60	158 + 53	2	Observed at Storehedinge.
104	18, 10	275 + 15	262 + 17	2	Observed at Odder.

No.	M. European Time.	Beginning.	End.	Mag.	Note.
105	Oct. 21, ^h 10 ^m 45 P.M.		Near β Urs. Maj.	*	Fireball, seen at Copenhagen, and Bornholm. Train in zm.
106	Nov. 16, 3 17 A.M.	^o 170 + ^o 35	^o 197 + ^o 41	2	Train, yellow.
107	34	167 + 25	176 + 17	3	
108	39	158 + 45	162 + 33	3	
109	39	154 + 50	166 + 68	2	
110	44	123 + 29	111 + 35	3	
111	48	166 + 7	174 + 1	4	Train. Nos. 106-111 observed at Odder.
112	17, (?)		N.N.E.	*	Fireball, seen at Aalborg. 10s.
113	Dec. 19 11 2 P.M.	90 + 8	88 - 9	*	Fireball, seen at Horsens. Red and blue.

Aurora Borealis.

A most magnificent display of northlight was seen here in Denmark on the night of September 9-10. In Odder I observed the phenomenon from 8^h 30^m to 11^h 15^m P. M., and noted all remarkable circumstances. At 9^h 30^m and again at 9^h 42^m the corona appeared near ε *Cygni*. At this moment the electric bells in the great telegraph station at Fredericia rang without any visible cause, and the telegraphic service was disturbed for hours during the auroral displays. A very large sun-spot crossed the Sun's central meridian at this very time, and its connection with the northlight is evident. Also it may be noted that we had very hot weather, unusual for the season, in the beginning of September, October, and November — and every time large sun-spots were observed.

PLANETARY PHENOMENA FOR MARCH AND
APRIL, 1899.

BY PROFESSOR MALCOLM McNEILL.

MARCH.

Mercury is an evening star during the whole month, and for the latter half of the month it is far enough away from the Sun to be seen in the evening twilight. It comes to greatest eastern elongation with the Sun on March 24th, and on that date sets a little more than an hour and a half after sunset.

Venus is still a morning star, having passed its greatest western elongation on February 10th. Owing to its greater south declination the interval between the time of sunrise and the rising of the planet is much less than the interval between times of transit, and at the close of the month the former interval is only a little more than an hour and a half. During March *Venus* moves 36° east and 8° north through the constellation *Capricorn* into *Aquarius*. The Moon passes a short distance north of the planet on the morning of March 8th, and will occult it for some places.

Mars sets somewhat earlier than before, but still remains above the horizon until long after midnight. It is in the constellation *Gemini*, and moves 6° eastward and 2° southward from a point 7° south of *Castor* (α *Geminorum*), the northerly one of "the twins," to a point nearly on the line from *Castor* to *Pollux* (β *Geminorum*), and at a distance from the latter about equal to the distance between *Castor* and *Pollux*. Its distance in millions of miles from the Earth increases from 80 to 103, and its brightness diminishes nearly in the ratio of the inverse squares of those numbers.

Jupiter is gradually getting into position for evening observation. At the close of the month it rises before 9 P. M. It is in the western part of the constellation *Libra*, and moves about 2° westward and 1° northward away from α *Libræ* and toward *Spica* (α *Virginis*).

Saturn rises two hours earlier than in February. It lies on the border of the constellations *Ophiuchus* and *Sagittarius*, and moves about 1° eastward during the month.

Uranus rises about an hour earlier than *Saturn*. It is in the constellation *Scorpio*, about 5° north of the principal star, *Antares*, and it moves a fraction of a degree westward during the month.

Neptune is in the extreme eastern part of *Taurus*.

APRIL.

Mercury is an evening star at the beginning of the month, setting considerably more than an hour after sunset, but it rapidly approaches the Sun, and passes inferior conjunction on April 12th. It then rapidly recedes from the Sun, and by the end of the month rises nearly an hour before sunrise.

Venus and the Sun are coming nearer together, and by the

end of the month the planet rises less than an hour and a half before sunrise. It moves 33° eastward and 11° northward through the constellation *Aquarius* into *Pisces*.

Mars is still above the horizon until after midnight. It is in the constellation *Gemini* at the beginning of April, and during the month it moves about 12° eastward and 3° southward from a point nearly on line with *Castor* and *Pollux* to a point between γ *Cancr*i and the "bee-hive" cluster in *Cancer*. It reaches its maximum distance from the Sun on April 8th, and its distance from the Earth increases from 103,000,000 to 130,000,000 miles.

Jupiter is above the horizon nearly the entire night, and it comes to opposition with the Sun on April 25th. It moves westward about 3° and northward 1° . It lies between α *Librae* and α *Virginis*, a little nearer the former, and toward the close of the month is about 1° north of γ *Virginis*.

Saturn toward the close of the month rises at a little after 10 P. M. It is in about the same position among the stars as before; but on April 2d it begins to retrograde; and at the end of the month it is in just about the same position it occupied on March 1st.

Uranus rises two hours earlier than during March, and has about the same position among the stars. It is about 5° north of *Antares* (α *Scorpii*), and moves a little less than 1° westward.

Neptune retains its position in *Taurus*.

EXPLANATION OF THE TABLES.

The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m . To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time, if the place is west of the standard meridian, and *subtracting*, if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are

roughly computed for lat. 40° , with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

PHASES OF THE MOON, P. S. T.

			H.	M.			H.	M.
Last Quarter,	Mar. 4,	8	7	P. M.	Apr. 3,	3	56	A. M.
New Moon,	Mar. 11,	11	53	A. M.	Apr. 9,	10	21	P. M.
First Quarter,	Mar. 18,	7	24	P. M.	Apr. 17,	2	43	P. M.
Full Moon,	Mar. 26,	10	18	P. M.	Apr. 25,	11	22	A. M.

THE SUN.

1898.	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° ' "	H. M.	H. M.	H. M.
Mar. 1.	22 49	— 7 33	6 39 A.M.	12 13 P.M.	5 47 P.M.
11.	23 26	— 3 41	6 22	12 10	5 58
21.	0 2	+ 0 16	6 6	12 7	6 8
Apr. 1.	0 42	+ 4 34	5 49	12 4	6 19
11.	1 19	+ 8 21	5 33	12 1	6 29
21.	1 56	+ 11 53	5 18	11 59 A.M.	6 40
May 1.	2 34	+ 15 5	5 5	11 57 A.M.	6 49

MERCURY.

Mar. 1.	22 58	— 8 27	6 50 A.M.	12 21 P.M.	5 52 P.M.
11.	0 7	+ 0 25	6 50	12 51	6 52
21.	1 6	+ 8 56	6 40	1 11	7 42
Apr. 1.	1 35	+ 13 22	6 10	12 56	7 42
11.	1 21	+ 11 3	5 22	12 0 M.	6 38
21.	1 1	+ 6 13	4 45	11 4 A.M.	5 23
May 1.	1 6	+ 4 26	4 15	10 30 A.M.	4 45

VENUS.

Mar. 1.	19 46	— 19 14	4 17 A.M.	9 9 A.M.	2 1 P.M.
11.	20 32	— 17 40	4 18	9 16	2 14
21.	21 19	— 15 16	4 16	9 23	2 30
Apr. 1.	22 9	— 11 47	4 10	9 30	2 50
11.	22 54	— 8 1	4 3	9 36	3 9
21.	23 38	— 3 49	3 53	9 41	3 29
May 1.	0 22	+ 0 38	3 43	9 45	3 47

MARS.

Mar. 1.	7 27	+ 25 37	1 14 P.M.	8 49 P.M.	4 24 A.M.
11.	7 30	+ 25 11	12 40	8 13	3 46
21.	7 38	+ 24 36	12 12	7 42	3 12
Apr. 1.	7 50	+ 23 46	11 44 A.M.	7 11	2 38
11.	8 5	+ 22 51	11 23	6 46	2 9
21.	8 21	+ 21 47	11 5	6 23	1 41
May 1.	8 39	+ 20 32	10 48	6 1	1 14

JUPITER.

Mar. 1.	14 33	— 13 35	10 45 P.M.	3 58 A.M.	9 11 A.M.
Apr. 1.	14 25	— 12 54	8 34	1 49	7 4
May 1.	14 11	— 11 43	6 12	11 32 P.M.	4 52

SATURN.

Mar. 1.	17 29	— 21 50	2 12 A.M.	6 54 A.M.	11 36 A.M.
Apr. 1.	17 33	— 21 50	12 3	4 55	9 37
May 1.	17 30	— 21 47	10 13 P.M.	2 55	7 37

URANUS.

Mar. 1.	16 25	— 21 32	1 7 A.M.	5 50 A.M.	10 33 A.M.
Apr. 1.	16 24	— 21 31	11 4 P.M.	3 47	8 30
May 1.	16 21	— 21 23	9 3	1 46	6 29

NEPTUNE

Mar. 1.	5 25	+ 21 54	11 29 A.M.	6 48 P.M.	2 7 A.M.
Apr. 1.	5 26	+ 21 57	9 28	4 47	12 6
May 1.	5 29	+ 22 0	7 33	2 52	10 11 P.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

	H.	M.		H.	M.
II, D,	Mar. 1.	8 5 P.M.	II, D,	Apr. 2.	7 44 P.M.
I, D,	3.	11 13	I, D,	3.	1 14 A.M.
II, D,	8.	10 40	I, D,	4.	7 43 P.M.
I, D,	11.	1 6 A.M.	II, D,	9.	10 20
I, D,	12.	7 34 P.M.	I, D,	10.	3 8 A.M.
II, D,	16.	1 15 A.M.	I, D,	11.	9 36 P.M.
I, D,	18.	2 59	I, D,	17.	12 56 A.M.
I, D,	19.	9 28 P.M.	I, D,	18.	11 30 P.M.
III, D,	20.	8 49	I, D,	20.	5 58
III, R,	20.	10 27	III, D,	25.	4 40
II, D,	23.	3 50 A.M.	III, R,	25.	6 14
I, D,	26.	11 21 P.M.	II, R,	27.	7 5
III, D,	28.	12 46 A.M.	I, R,	27.	9 59
III, R,	28.	2 24	I, R,	29.	4 28

(THIRTY-THIRD) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to C. D. PERRINE, Assistant Astronomer in the Lick Observatory, for his discovery of an unexpected comet on September 13, 1898.

The Committee on the Comet-Medal,

JAMES E. KEELER,
CHAS. BURCKHALTER,
WM. M. PIERSON.

January 26, 1899.

(THIRTY-FOURTH) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to WM. R. BROOKS, of Smith Observatory, Geneva, N. Y., for his discovery of an unexpected comet on October 20, 1898.

The Committee on the Comet-Medal,

JAMES E. KEELER,
CHAS. BURCKHALTER,
WM. M. PIERSON.

January 26, 1899.

(THIRTY-FIFTH) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to FREDERICK L. CHASE, of Yale University Observatory, New Haven, Conn., for his discovery of an unexpected comet on November 14, 1898.

The Committee on the Comet-Medal,

JAMES E. KEELER,
CHAS. BURCKHALTER,
WM. M. PIERSON.

January 26, 1899.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

PHOTOGRAPH OF THE GREAT NEBULA IN *ORION*, TAKEN WITH THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.

The photograph of the Nebula in *Orion*, which forms the frontispiece of the present number of these *Publications*, is the first (and possibly the best) of a considerable number of photographs of the same object recently taken with the Crossley 3-foot reflector of the Lick Observatory. The exposure given to the negative was forty minutes, on a fine, clear night when the nebula was only a little east of the meridian.

The half-tone cut, while not bad as such process illustrations go, does scanty justice to the original negative, which is a very fine one. Only the most expensive processes give satisfactory results in reproducing such subjects as this, and even they are much inferior to glass transparencies, which have a far greater scale of intensity. On the original negative the mottled details of the bright Huyghenian region are shown with much perfection, stars are distinct throughout the entire nebula, and the trapezium stars are clearly separated, while loops of faint nebulosity extend beyond the limits of the plate. In the reproduction these features are practically lost, and there is an abrupt transition of brightness, which is due to a defect of the process.

In exposing and developing the negative the aim was to obtain the best general view of the nebula, and not to show its greatest possible extent. Therefore very full exposure was given, and the development was stopped long before all the nebulosity had appeared which an exposure of forty minutes is capable of showing. In this way, as all photographers are aware, the contrasts between differently bright parts of an image are diminished.

The photographic power of the Crossley reflector on a fine night is surprising,—at least to one who has hitherto worked

* Lick Astronomical Department of the University of California.

with refractors only. In the case of the *Orion* nebula, the amount of nebulosity shown in the frontispiece is easily obtained with an exposure of five minutes, though at the expense of all detail in the central parts. The Huyghenian and adjoining brighter regions can be photographed in thirty seconds. Comparison with earlier results obtained with the photographic lens of the great refractor (33 inches aperture) shows that with the Crossley reflector more nebulosity is shown in ten minutes than can be obtained with the refractor in three hours. The great superiority of the reflector indicated by this test is due partly to its much greater angular aperture, and partly to the fact that the thick lenses of the refractor strongly absorb the photographically active rays of the nebula, which, as shown by the spectrum, are largely of quite short wave-lengths.

It should be added that the large mirror of the Crossley reflector has not yet been resilvered. It has been repolished, but the surface is spotted and not nearly as bright as it can be made.

J. E. K.

SECOND NOTE ON THE MINOR PLANET DQ.

When the little planet DQ was discovered last August by Dr. WITT, at the Urania Observatory, Berlin, it was at once noted that its motion was very rapid, thus indicating a marked difference between its orbit and those of the other asteroids. This has been abundantly verified, first by the elements of its orbit computed soon after its discovery by Dr. BERBERICH, and, later, by those obtained by Messrs. CHANDLER, FAYET, HUSSEY, MILLOSEVICH, and RUSSELL.

DQ has the shortest periodic time of any asteroid known. While all the others require from 3.0 to 8.4 years to complete a revolution about the Sun, it requires only 643 days, or 1.76 years. In the course of forty-four years it makes very nearly twenty-five sidereal revolutions; so that after this interval it and the Earth occupy again at the same time very nearly the same positions in their orbits, and therefore sustain to each other nearly the same general relations.

The orbit of DQ is to be classed with those having rather high eccentricities. On the average, only one asteroid out of seven has a higher value of this element. On account of the magnitude of its eccentricity, the distance of DQ from the Sun has a range of over 60,000,000 miles, the minimum being a little

more than 105,000,000, and the maximum about 165,600,000. At perihelion it approaches within 14,000,000 miles of the orbit of the Earth, and at aphelion it recedes 24,000,000 miles beyond the mean distance of *Mars*.

Great interest centers in the planet DQ solely on account of the nearness with which it approaches the Earth, and the use that can be made of it by reason of this circumstance in determining the value of the solar parallax and those of related astronomical constants with a higher degree of precision than has hitherto been attained.

It will be remembered that many methods have been proposed for determining the value of the solar parallax, or its equivalent, the mean distance of the Earth from the Sun. The attempts to obtain the value of this fundamental constant, the unit of astronomical distances, by direct means, have proved absolute failures. All the methods giving values at all acceptable have been indirect. In these the measurements are made, not upon the Sun, but upon other bodies, and for the determination of quantities which are known functions of the Earth's distance from the Sun.

Among such methods, the observations of the transits of *Venus*, made at widely separated stations, promised great accuracy. But, unfortunately, there were unexpected difficulties, and in many cases, even after the observations had been obtained, there were uncertainties as to just what had been observed. On this account, these observations have received a variety of interpretations, and in the hands of different computers have yielded various discordant values of the solar parallax.

Gravitational astronomy has furnished several methods of obtaining the solar parallax, but always in connection with the determination of other astronomical constants, or in some way more or less dependent upon them. Thus, it may be deduced from the lunar inequality of the Earth's motion, from the parallactic inequality of the Moon, from the mass of the Earth as derived from the secular variations of the elements of the interior planets, etc. It may also be obtained by combining the measured velocity of light with the light equation, and by combining the velocity of light with the constant of aberration. But all these constants are in themselves subject to uncertainties, and it is highly desirable to obtain the solar parallax independently of them, and then to use it, if need be, in verifying their values.

The most accurate independent method of obtaining the value of the solar parallax that has been practically tested is the measurement of the displacements of the nearer asteroids among the stars about the time of opposition. *Mars* has been used for the same purpose; but on account of its large disk and other peculiarities, it is not easy to measure its distance from the stars and secure results free from large systematic errors. On the other hand, the asteroids have precisely the same appearance as the fixed stars, and submit to measurement with like facility and like precision. In parallax determinations they have already furnished results among the best.

Concerted observations were made in 1888 on the planet *Iris*, and in 1889 on *Victoria* and *Sappho* at the Cape of Good Hope, in the southern hemisphere, and, in part, at New Haven, Göttingen, Leipzig, Bamberg, and Oxford, in the northern hemisphere, from which the following very accordant values of the solar parallax have been derived:—

	Mean Solar Parallax.	Probable Error.	Weight.
From <i>Victoria</i> ,	8".8013	0".0061	2.69
From <i>Sappho</i> ,	8 .7981	0 .0114	0.77
From <i>Iris</i> ,	8 .8120	0 .0090	1.23

These separate values have an extreme variation of only 139 ten-thousandths of a second of arc, or the angle which a foot rule would subtend at a distance of 2,810 miles. This sufficiently indicates the precision attainable by this method. We are not to suppose, however, that the results here quoted have the accuracy demanded by modern astronomy. This may be appreciated the better, when we remember that a difference of only 0".0139 in values of the solar parallax corresponds to nearly 148,000 miles, or to considerably more than half of the distance from the Earth to the Moon.

The observations from which the above values of the solar parallax were derived were made when the planets *Iris*, *Victoria*, and *Sappho* were not far from a unit of distance from the Earth. At the most favorable oppositions, those occurring about the 20th of January, the distance of the new planet DQ is only about one seventh as great. If observations be made upon it in the same manner, and if in them there is practical freedom from systematic errors, they should furnish a value of the solar parallax with the uncertainties correspondingly diminished.

From observations of August 15th, September 27th, and November 11th, I have computed the following new elements of the orbit of the planet DQ :—

Epoch 1898. August 31.5, Gr. M. T.

$$\begin{array}{rcl} M = 221^{\circ} 33' 29''.1 \\ \omega = 177 \quad 41 \quad 21 \quad .0 \\ \Omega = 303 \quad 30 \quad 19 \quad .2 \\ i = 10 \quad 49 \quad 33 \quad .5 \\ \phi = 12 \quad 52 \quad 16 \quad .1 \end{array} \left. \vphantom{\begin{array}{l} M \\ \omega \\ \Omega \\ i \\ \phi \end{array}} \right\} 1898.0$$

$$\log a = 0.163710$$

$$\mu = 2015''.773$$

$$\text{Period} = 642.929 \text{ days}$$

For my observation of January 3, 1899, these elements give the following residuals :—

$$O-C: \Delta \alpha = + 0''.36, \quad \Delta \delta = - 0''.1$$

This observation was obtained fifty-five days after the last observation upon which the elements were based.

In the *Astronomical Journal*, No. 452, Dr. CHANDLER has given the following elements :—

Epoch 1898. August 31.5, Gr. M. T.

$$\begin{array}{rcl} M = 221^{\circ} 35' 45''.6 \\ \omega = 177 \quad 37 \quad 56 \quad .0 \\ \Omega = 303 \quad 31 \quad 57 \quad .1 \\ i = 10 \quad 50 \quad 11 \quad .8 \\ \phi = 12 \quad 52 \quad 9 \quad .8 \end{array} \left. \vphantom{\begin{array}{l} M \\ \omega \\ \Omega \\ i \\ \phi \end{array}} \right\} 1898.0$$

$$\log a = 0.1637876$$

$$\mu = 2015''.2326$$

$$\text{Period} = 643.10 \text{ days}$$

This is the third system of elements of DQ published by Dr. CHANDLER. He has obtained them by correcting his previous elements so as to represent the positions of the planet derived from photographic plates taken at Arequipa in 1896. The planet has also been found upon plates taken in 1893 and 1894, and its positions for certain dates in these years have been obtained from them. These positions will be very useful in an early determination of more accurate elements of the orbit.

The longitude of perihelion of DQ is approximately 121° . The heliocentric longitude of the Earth has this value about the

21st of January. Therefore, when an opposition of the planet occurs at this date, its distance from the Earth will be a minimum, and the planet will be most favorably situated for the determination of the solar parallax.

According to my elements, the next date of perihelion passage is May 6, 1899. Assuming the periodic time of the planet to be exactly 643 days, which is very nearly the mean of the two values given above, and neglecting perturbations, I have found the following approximate dates of perihelion passage from 1850 to 1938, or through two complete cycles, so far as relates to the motion of the planet with reference to that of the Earth.

It will be noted that the opposition 1901 will be the most favorable for determining the solar parallax of any until those of 1923, 1931, and 1938. It is unfortunate that the planet was not discovered some years ago, so that parallax observations could have been made at the very favorable opposition of 1894.

Jan.	19, 1850	Jan.	23, 1894
Oct.	26, 1851	Oct.	28, 1895
July	28, 1853	Aug.	1, 1897
May	2, 1855	May	6, 1899
Feb.	3, 1857	Feb.	8, 1901
Nov.	8, 1858	Nov.	13, 1902
Aug.	12, 1860	Aug.	17, 1904
May	17, 1862	May	22, 1906
Feb.	19, 1864	Feb.	24, 1908
Nov.	23, 1865	Nov.	28, 1909
Aug.	28, 1867	Sept.	2, 1911
June	1, 1869	June	6, 1913
March	7, 1871	March	11, 1915
Dec.	8, 1872	Dec.	13, 1916
Sept.	12, 1874	Sept.	17, 1918
June	16, 1876	June	21, 1920
March	21, 1878	March	26, 1922
Dec.	24, 1879	Dec.	29, 1923
Sept.	27, 1881	Oct.	2, 1925
July	2, 1883	July	7, 1927
April	5, 1885	April	10, 1929
Jan.	8, 1887	Jan.	13, 1931
Oct.	12, 1888	Oct.	17, 1932
July	17, 1890	July	22, 1934
April	30, 1892	April	24, 1936
Jan.	23, 1894	Jan.	27, 1938

DQ has recently received the name *Eros*.

MT. HAMILTON, January 20, 1899.

W. J. HUSSEY.

A NEW DOUBLE STAR.

Three of the comparison stars used in observations of Comet *b* 1898 were found to be double. The stars were *Harvard* A. G. 2140, 2353, and 2368. On nights when they were conveniently situated, and could be measured with but little loss of time, a set of measures was secured. Later the best known catalogues of double stars were examined, and two of the stars were found to be Σ pairs, 2140 = Σ 657, and 2353 = Σ 810. The star *Harvard* 2368, however, was not found, and upon referring the matter to Professor BURNHAM, he fails to find it in his very complete general catalogue of double stars. Following are the three measures secured of it:—

<i>Harvard</i> A. G. 2368. α 5 ^h 49 ^m 20 ^s , δ + 52° 41'. (1875.O.)							
							Wt.
1898.69	306°.9	1".81	9.0	9.3	36	520	2
1898.85	307 .2	1 .91	9.0	9.3	36	520	2
1899.02	309 .0	2 .05	9.0	9.6	12	700	1
1898.82	307 .4	1 .90	9.0	9.4			

January 6, 1899.

C. D. PERRINE.

DOUBLE-STAR NOTES.

During the year 1898 measures of about 350 pairs of double stars were secured with the 36-inch and 12-inch telescopes. The list includes many stars showing rapid motion, the following being of special interest:—

β *Orionis* = β 555. The small star situated 9".62 from *Rigel* in position-angle 201°.8 is a very close double. BURNHAM suspected an elongation with his well-known 6-inch telescope as early as 1871, but observers with much larger instruments could not verify his suspicions. Mr. HERBERT SADLER independently suspected elongation a little later on, and in 1878 BURNHAM was able to secure measures with the 18½-inch telescope of the Dearborn Observatory. Later on, 1880 to 1882, he could not be sure of any elongation with that instrument, and in 1889–91 his repeated examination of the star with the 36-inch refractor showed it to be perfectly round. So far as I know, no further measures were made until my recent ones with the 36-inch, which give:—

	Angle.	Distance.	Seeing.
1898.794	175°.3	0".18	4
.878	181 .0	0 .13	3
.947	177 .6	0 .17	3

The elongation is certainly real, and taken in connection with BURNHAM's result in 1889-91, would seem to indicate very rapid motion. As the pair is out of reach of all but the largest telescopes, and is in good position for observing in the winter months only, when good nights are relatively few, it will probably be a long time before any definite knowledge of the character of the motion can be secured.

ε *Hydræ* AB. SCHIAPARELLI detected the duplicity of the principal star of the well-known Σ pair in 1888. He found from six nights' measures:—

	Angle.	Distance.
1888.28	142°.0	0".21

BURNHAM measured the pair with the 36-inch as follows:—

1888.98	154°.4	0".26	2 nights
1890.92	170°.0	0".19	2 nights
1892.18	179°.6	0".21	

showing that the pair was in rapid motion. I have measured it twice with the 36-inch, obtaining—

1898.137	250°.7	0".18
1899.024	259°.9	0".25

As the Σ pair also shows orbital motion this forms a most interesting ternary system.

48 *Cassiopeiæ* = β 513. The mean of BURNHAM's discovery measures and those made by DEMBOWSKI the same year is—

1878.7	264°.75	1".04
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Subsequent measures by BURNHAM with the 36-inch showed that the angle was increasing and the distance diminishing. As the result of three nights' measures with the 36-inch under good conditions, I find—

1898.92	5°.9	0".36
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showing an increase of angle of over 100° in twenty years. While it is too soon to make positive statements, it is altogether probable that the motion is orbital.

Procyon was measured on three nights with the mean result:—

1898.76	330°.9	4".97
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Since its discovery by Professor SCHAEFERLE, in November, 1896, the companion has moved through an arc of more than 12°, without sensible change of distance.

Measures of the companion of *Sirius* indicate that it is following very closely the best recent orbits.

H 529. PORTER gives the principal star of this pair the large proper motion of $0''.900$ in $154^{\circ}.6$. HERSCHEL estimated $120^{\circ} 20''$, but no measure of the pair was made until two years ago, when I obtained, from three nights' measures with the 12-inch—

1896.51	$120^{\circ}.4$	$17''.30$	Magnitudes. 9—10
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Recent measures on two nights with the same instrument give:—

1898.86	$121^{\circ}.0$	$17''.56$
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This proves that the two stars are moving together. It is rather unusual to find such strong evidence of physical connection between two faint stars so far apart. The position of the star for 1900.0 is R. A. $13^h 14^m 54^s$; Decl. $+ 35^{\circ} 40'$.

LICK OBSERVATORY, January 20, 1899. R. G. AITKEN.

TWO NEW PLANETS DISCOVERED AT THE LICK OBSERVATORY.

On the night of October 13, 1898, I made an exposure, two hours in length, with the Crocker photographic telescope; and upon the plate obtained I found the trails of three asteroids, two of which proved to be new. These have been designated, provisionally, 1898 EB, and 1898 EC.

I have since secured a number of observations of each of these planets, and have determined the elements of their orbits as follows:—

Elements of Planet 1898 EB.

Epoch Berlin M. T. 1898, Oct. 14.5

$$\begin{array}{rcl} M = 310^{\circ} & 47' & 3''.7 \\ \omega = 232 & 56 & 55.4 \\ \Omega = 202 & 26 & 1.5 \\ i = 19 & 13 & 27.5 \\ \phi = 4 & 19 & 19.9 \end{array} \left. \vphantom{\begin{array}{l} M \\ \omega \\ \Omega \\ i \\ \phi \end{array}} \right\} 1899.0$$

$$\log a = 0.466958$$

$$\mu = 637''.631$$

$$P = 2032.52 \text{ days.}$$

The above elements were computed from observations made on October 14, November 3, and November 16, 1898. At the time of discovery the brightness of this planet was estimated at 11.5th magnitude.

Elements of Planet 1898 EC.

Epoch Berlin M. T. 1898, Oct. 18.5

 $M = 284^{\circ} 59' 46''.6$ $\omega = 175 \quad 59 \quad 19 \quad .2$ $\Omega = 292 \quad 17 \quad 43 \quad .3$ $i = 1 \quad 35 \quad 48 \quad .8$ $\phi = 6 \quad 17 \quad 1 \quad .8$ $\log a = 0.345198$ $\mu = 1076''.988$ $P = 1203.36 \text{ days.}$

These elements were computed from one normal place of October 18, (six observations), and single observations of November 3 and November 17, 1898. At the time of discovery the brightness of this planet was estimated at 12.5th magnitude.

Mt. HAMILTON, January 16, 1899.

E. F. CODDINGTON.

PROBABLE PROPER MOTION OF HARVARD A. G. 2577.

This star was used as a comparison star in observations of Comet *b* 1898, along with others on the same nights. Discrepancies in the observations led to a direct comparison of this star with others, and subsequently a reobservation of this star with the meridian-circle by Professor TUCKER. The star's R. A. is found to be substantially the same as that of the A. G. catalogue, but its declination is $6''$ less. This difference is probably due to a proper motion of $0''.25$ per year, although there is an incomplete observation at Bonn, in 1860, which differs considerably in both co-ordinates from such an assumption.

Mt. HAMILTON, Dec. 20, 1898.

C. D. PERRINE.

COMET DISCOVERIES OF THE YEAR 1898.

In the number of cometary discoveries the year 1898 has surpassed all previous records. Ten comets in all were found during the year, three being returns of well-known members of the solar system, and the remaining seven unexpected. It is worthy of note also that all ten passed perihelion in little more than eight months—between March 20 and November 23, 1898. The Lick Observatory contributed six to this list of discoveries, three of the unexpected comets having been picked up by Mr. PERRINE, and one by Mr. CODDINGTON—the last named by photography—while the rediscovery of WINNECKE's and

WOLF's periodic comets were due to Mr. PERRINE and Mr. HUSSEY, respectively. Of the three remaining new comets one was found by Mr. GIACOBINI, at Nice, one by Dr. BROOKS, at Geneva, N. Y., and one by Mr. CHASE, at Yale. The rediscovery of ENCKE's periodic comet by Mr. JOHN GRIGG, at Thames, New Zealand, on June 7th, completes the list. Five of these discoveries were made between the dates June 7th and June 19th, three of them at the Lick Observatory in less than a week.

According to DENNING, the largest number of comets found in any previous year is eight, that many having been found in 1858. Nine comets passed perihelion in 1886, but two were found in 1885 before coming to perihelion, and one in January, 1887, after perihelion passage.

Aside from their number, the cometary discoveries of the past year are interesting for several other reasons. Previous to 1898 only two comets had been discovered by photography,—BARNARD's, in October, 1892, and SCHAEBERLE's, on the plates of the total solar eclipse of April, 1893. The former of these only was verified by later visual observation. The year 1898 adds two more to the list of photographic discoveries, CODDINGTON's and CHASE's, both being afterward observed visually. CODDINGTON's comet was so bright that an independent visual discovery of it was made three days later by W. PAULY, at Bucharest; but CHASE's, which was found on plates exposed to photograph the *Leonid* meteors, on November 14th, was so faint that it would in all probability have escaped visual discovery.

Again, at least two of the comets of the year bear close resemblance in their orbits to comets of previous years, as has been pointed out in previous numbers of these *Publications*.* Comet *b* (PERRINE), for which PERRINE finds a period of 305 years, apparently belongs to the same family as the comet of 1684, and 1785 I; and the resemblance between the orbits of Comet *i* (BROOKS) and SCHAEBERLE's Comet of 1881 is remarkable.

But the most interesting point to many minds in the year's cometary work is the accurate agreement between mathematical calculation and the actual motion of a comet shown in the rediscovery of WOLF's periodic comet. From observations made during previous apparitions, THRAEN computed the definitive elements of the comet's orbit, and upon these based the com-

* See Nos. 62, p. 118, and 65, pp. 243, 250.

putation of its path during the present apparition, taking into account, of course, the perturbing influence of the planets. So well was his work done, and so accurate the theory upon which it was based, that the comet was found by HUSSEY within 1" of Right Ascension, and 4" of Declination, of the predicted place.

The following tabulation gives the comets of the year in the order of their perihelion passage, the discoverer, and the date of discovery:—

Comet.	Discoverer, and Date of Discovery.	Remarks.
I	PERRINE, . Mar. 20	Elliptic; with period of more than 300 years.
II	PERRINE, . Jan. 2	WINNECKE's periodic comet; period, 5.8 years.
III	GRIGG, . . June 7	ENCKE's periodic comet; period, 3.3 yrs. Independently discovered, June 11th, by TERBUT, from whom the first announcement of discovery was received.
IV	HUSSEY, . June 16	WOLF's periodic comet; period, 6.8 yrs.
V	GIACOBINI, June 19	
VI	PERRINE, . June 14	
VII	CODDINGTON, June 11	By photography. Independently discovered visually by W. PAULY, at Bucharest, on June 14th.
VIII	CHASE, . Nov. 14	On meteor plates; announcement made Nov. 24th.
IX	PERRINE, . Sep. 13	Independently discovered by M. P. CHOLFARDET, at Besançon, on Sept. 14th.
X	BROOKS, . Oct. 20	

January 9, 1899.

R. G. AITKEN.

THE PROBABLE STATE OF THE SKY ALONG THE PATH OF TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

The observations taken under the direction of the United States Weather Bureau in 1897, to determine the meteorological conditions likely to prevail along the path of the total eclipse of the Sun, which will occur in the Southern States on May 28, 1900,* were repeated this year on precisely the same plan. In general, the work was done by the same observers, and eighty-seven stations reported this year as against sixty-six last year.

The results, which are summarized by Professor BIGELOW in the *Monthly Weather Review* for September, 1898, lead to the

* See abstract of Professor BIGELOW's Report in No. 60 of these *Publications*.

same conclusion reached last year, which is as follows: "The weather conditions in the interior of Georgia and Alabama were better than in Virginia, North Carolina, South Carolina, Mississippi, and Louisiana; and judging from this table [of results of the observations] it would be much safer for the eclipse expeditions to locate their stations in the northern portions of Georgia and Alabama, upon the southern end of the Appalachian Mountains, where the track crosses the elevated areas, than nearer the coast-line in either direction, northeastward toward the Atlantic Coast, or southwestward toward the Gulf Coast; on the Coast itself the weather is more unfavorable than in any other portion of the track." These observations will be repeated in 1899.

R. G. A.

ON THE ORIGIN OF THE PRINCIPAL LINE IN THE AURORA SPECTRUM.

It is possible that some recent observations may furnish an explanation of the origin of the principal bright line in the spectrum of the aurora.

When the new element, krypton, was discovered in our atmosphere by RAMSAY and TRAVERS, they announced that one of the principal lines in its spectrum has the wave-length 5566 tenth-meters. Professor RUNGE has made an accurate determination of the wave-length of this line, and finds its value to be

$$\lambda 5570.4.$$

The observations of the aurora line, made under the best conditions, gave the following results for its wave-length:—

ÅNGSTRÖM . . .	5568
VOGEL . . .	5572
VIJKANDER . . .	5573
LEMSTRÖM . . .	5570
HUGGINS . . .	5572
COPELAND . . .	5573
GILLENSKIÖLD . .	5569
CAMPBELL . . .	5571.6
Mean . . .	5571.1

It will be seen that the krypton and aurora lines occupy nearly the same position. Inasmuch as the aurora line was quite faint when some of the measures were made, it is possible

that its measured position could be in error by 0.7 of a unit, thus permitting exact coincidence with the krypton line.

It does not follow that the apparent coincidence indicates with any degree of certainty that the principal aurora line is due to krypton. We need only recall the early observations of the principal nebular line, and its apparent coincidence with a prominent nitrogen line, and later with a prominent magnesium line, to be on our guard against conclusions based upon apparent coincidences of single lines in two spectra. In the present case, only one of the several krypton lines seems to have a counterpart in the aurora spectrum.

Again, we should recall that LIVEING and DEWAR produced a strong line at λ 5572 by passing a powerful current (spark) of electricity through liquid oxygen and its vapor. This points to the possible oxygen origin of the aurora line.

W. W. CAMPBELL.

CORRECTIONS TO WEISSE'S CATALOGUE OF BESSEL STARS.

W. B., 22^a 259.

There appears to be an error of about 10'' in declination in the reduction of this star from the time of observation to the epoch of the catalogue. The declination should be increased 10''.

W. B., 22^a 395.

The right ascension of this star appears to be 0^h.6 too large.

W. B., 22^a 688.

The declination of this star is in error by 1' 45''. Both the catalogue place and the zone observation should be decreased.

Mt. HAMILTON, Dec. 20, 1898.

C. D. PERRINE.

COMET *j* 1898 (CHASE).

This comet was discovered November 21, 1898, at the Yale Observatory by Dr. FREDERICK L. CHASE upon photographic plates exposed upon the night of November 14, 1898, for the *Leonid* meteors. Its cometary nature was verified by Dr. CHASE upon the night of November 21, 1898, by making additional exposures.

The comet has also been found upon negatives taken at Harvard College Observatory, at Goodsell Observatory, and at the Lick Observatory.

When discovered, its brightness was estimated to be about 11th magnitude. Theoretically, its maximum brightness was reached about January 1, 1899, and it is now slowly decreasing. By April 1st it will have decreased to about half that at discovery.

From my observations of November 23, December 7, and December 16, 1898, I have computed the following elements for this comet. The first two observations were secured with the 12-inch telescope and the third with the 36-inch refractor:—

Elements.

$$T = 1898 \text{ Sept. } 20.15344$$

$$\left. \begin{array}{l} \omega = 4^{\circ} \ 37' \ 59''.9 \\ \Omega = 95 \ 51 \ 35.9 \\ i = 22 \ 30 \ 20.3 \end{array} \right\} 1899.0$$

$$\log q = 0.358892$$

A comparison of the ephemeris computed from these elements with observations which I have recently secured with the 36-inch refractor gives the following residuals:—

O—C.

$$\text{Jan. } 4, \quad \Delta \alpha = + 0''.19, \quad \Delta \delta = + 2''.2$$

$$5, \quad \Delta \alpha = + 0.17, \quad \Delta \delta = + 1.5$$

Soon after the first elements of this comet were published, Professor WEISS, of Vienna, pointed out their similarity to those of Comet 1867 I, and suggested the possibility of an identity. But the residuals given above for dates twenty and twenty-one days after the date of the last observation which was used in computing these elements, show that they are nearly correct, and that the true elements are essentially parabolic. There is, therefore, no probability of the present comet being a return of Comet 1867 I.

MT. HAMILTON, January 16, 1899.

E. F. CODDINGTON.

THE SECOND WASHINGTON STAR CATALOGUE.

This catalogue, which embodies 72,914 observations of stars made with the 8.5-inch transit-circle at the old Naval Observatory between the dates January 3, 1866, and June 30, 1891, was published in November, 1898, as "Appendix I," of the Washington Observations for 1892. It contains the places for 1875.0 of 5151 stars, 185 of which are stars of the American Ephemeris, and the others miscellaneous, ranging in Declination from the North

Pole to 45° south, and in magnitude from naked-eye stars to stars of the 12th magnitude. The number of observations for a star varies from 1 for some in the miscellaneous list to 855 in Right Ascension, and 2187 in Declination for *Polaris*.

The title-page rightfully bears the name of Professor JOHN R. EASTMAN, as 17,334 of the observations were made by him personally, and 39,867 others under his immediate direction; while the reduction, the discussion of the results, and the arrangement of the volume were carried out according to his plans. R. G. A.

THREE NEW SPECTROSCOPIC BINARY STARS.

While engaged in determining the velocities of stars in the line of sight with the Mills spectrograph, we have found three stars whose velocities are variable. The variation in each case is due to the fact that the star is describing an orbit of comparatively short period.

η Pegasi. ($\alpha = 22^h 38^m$, $\delta = + 29^\circ 42'$.)

My first measures of the velocity of this star from three spectrum plates gave $+ 7.1$, $+ 5.1$, and $- 2.2$ kilometers per second, respectively. Inasmuch as an extreme range of four kilometers for a star of constant velocity is never expected, I felt sure that the velocity of *η Pegasi* varied. Additional plates were secured and another earlier plate was reduced. All confirm the variation. The velocities obtained up to date are as follows:—

1896.	Aug. 27.	$+ 7^{km}.1$
	Sept. 23.	$+ 5 .1$
1897.	July 8.	$- 6 .4$
	Sept. 28.	$- 2 .2$
1898.	Aug. 29.	$+ 16 .5$
	Aug. 30.	$+ 15 .6$
	Sept. 4.	$+ 16 .5$
	Sept. 15.	$+ 15 .7$
	Oct. 18.	$+ 11 .0$
	Oct. 24.	$+ 11 .5$
	Oct. 26.	$+ 10 .8$
	Nov. 28.	$+ 6 .1$
1899.	Jan. 23.	$- 1 .6$

By plotting these data, it will be seen that the period of the star must be about two and a quarter years. Several years must elapse before a definitive determination of the orbit can be made.

• *Leonis*. ($\alpha = 9^h 36^m$, $\delta = +10^\circ 21'$.)

About twenty spectrum plates of this star have been secured. They show that the velocity varies between about +82 and -30 kilometers per second, completing one cycle in a period of fourteen and a half days. There is some evidence that the spectrum consists of two or more spectra superposed.

χ *Draconis*. ($\alpha = 18^h 23^m$, $\delta = +72^\circ 42'$.)

Fourteen plates of the spectrum of this star have been obtained and reduced, with the following results for the velocity:—

1898.	July 25.	+ 45 ^{km} .6
	Sept. 5.	+ 46 .0
	Sept. 19.	+ 42 .6
	Oct. 24.	+ 14 $\pm$
	Oct. 25.	+ 16 $\pm$
	Oct. 26.	+ 14 .5
	Nov. 1.	+ 11 .9
	Nov. 5.	+ 11 .3
	Nov. 12.	+ 10 .7
	Nov. 18.	+ 10 .6
	Dec. 3.	+ 15 $\pm$
	Dec. 7.	+ 18 .3
	Dec. 16.	+ 21 .0
	Dec. 17.	+ 20 .0

The observations seem to indicate a period of about six months.

W. W. CAMPBELL.

THE COPLEY MEDAL AWARDED TO SIR WILLIAM HUGGINS.

At the recent anniversary meeting of the Royal Society of London, the President announced that the Copley Medal had been awarded to Sir WILLIAM HUGGINS, for his great achievements in the application of spectrum analysis to the heavenly bodies.

TELESCOPES NEARING COMPLETION.

“The Sheepshanks Telescope Committee report that the erection of the polar-reflecting photographic telescope at the [Cambridge, England,] observatory, with its building and dome, is nearly complete. Dr. COMMON has provided the mirror, and the object-glass is one of COOKE's triple lenses. The tube and

apparatus are by Messrs. GRUBB. The adjustments and tests have still to be carried out."—*Nature*, December 8, 1898.

In connection with the above note, it will be of interest to add that two other important telescopes are nearly ready for use — the large 80^{cm} photographic telescope of the Potsdam Observatory, with a 50^{cm} visual guiding telescope; and the 24-inch photographic refractor for the Royal Observatory at the Cape of Good Hope.

ASTRONOMICAL TELEGRAMS.

(Translations).

BOSTON, Mass., November 23, 1898.

To Lick Observatory: (Received 11:10 P.M.)

A faint comet was discovered by CHASE, at Yale, on November 14.729 G. M. T., in R. A. $10^h 7^m 4^s$; Decl. $+ 22^\circ 55'$ (approximately). The daily motion in R. A. is $+ 24'$, in Decl. $+ 4'$.
(Signed) JOHN RITCHIE, JR.

Lick Observatory, Nov. 24, 1898.

To Harvard College Observatory: (Sent 10:30 A.M.)

Comet Chase was observed by Mr. E. F. CODDINGTON, on November 24.0519, in R. A. $10^h 21^m 48^s.1$; Decl. $+ 23^\circ 36' 6''$.

Lick Observatory, Nov. 25, 1898.

To Harvard College Observatory: (Sent 10:00 A.M.)

Comet Chase was observed by Mr. E. F. CODDINGTON, on November 25.0286, in R. A. $10^h 23^m 15^s.7$; Decl. $+ 23^\circ 40' 51''$.

Lick Observatory, Nov. 26, 1898.

To Harvard College Observatory: (Sent 10:00 A.M.)

Comet Chase was observed by Mr. E. F. CODDINGTON, on November 26.0569 G. M. T., in R. A. $10^h 24^m 47^s.5$; Decl. $+ 23^\circ 46' 11''$.

Lick Observatory, Nov. 26, 1898.

To Harvard College Observatory: (Sent 10:00 P.M.)

Elements and ephemeris of Comet Chase were computed by E. F. CODDINGTON and H. K. PALMER, as follows:—

T = G. M. T. 1899, April 10.65.

$\omega = 136^\circ 16'$	} Ecliptic and Mean Equinox of 1898.0
$\Omega = 107 \quad 11$	
$i = 33 \quad 42$	

natural $q = 0.6821$

[The ephemeris is here omitted.]

PRIZES AWARDED BY THE FRENCH ACADEMY OF SCIENCES FOR
THE YEAR 1898.

A long list of awards for distinguished services to science, made by the French Academy of Sciences at its annual meeting on December 19, 1898, is published in the *Comptes Rendus* for that date.

In the Department of Astronomy the awards are as follows:—

The Lalande Prize is awarded to Dr. S. C. CHANDLER for his services to astronomy. The discovery and proof of the variation of terrestrial latitudes, his work with the almucantar, his researches on variable stars, and upon the identity of Comet Brooks (1889 V) with LEXELL'S Comet, are especially mentioned.

The *Prix Damoiseau* was to be awarded for the best treatise on the "Theory of the Perturbations of *Hyperion*, One of the Satellites of *Saturn*." The only essay presented was that by Dr. G. W. HILL, of Washington, to whom the prize was awarded for this and his other researches in mathematical astronomy.

The Valz Prize goes to M. P. COLIN, the founder of the observatory at Tananarive, Madagascar, for his works on astronomy and geodesy.

The fourth astronomical prize, the *Prix Janssen*, is awarded to M. BELOPOLSKY, head of the Department of Astrophysics at the Pulkowa Observatory, for his spectroscopic work, especially in connection with spectroscopic binary stars.

Another award will be of interest to members of the Society — that of the Henry Wilde Prize to Dr. CHAS. A. SCHOTT, of the U. S. Coast and Geodetic Survey, for his valuable contributions to the study of terrestrial magnetism in the last thirty years.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY, JANUARY
28, 1899, AT 7:30 P. M.

President AITKEN presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 28, 1899.

Mrs. BEVAN	{ 46 Queen's Gate Terrace, S. W., London, England.
Prof. F. P. BRACKETT	{ Pomona College, Claremont, Cal.
Mr. EVERETT HAYDEN	{ The Observatory, Navy Yard, Mare Island, Cal.
Mr. JAMES D. MADDRILL	. 830 Eighteenth St., Oakland, Cal.
Prof. T. E. MCKINNEY	. Marietta College, Marietta, Ohio.
Mr. ERNEST K. RODEN	{ International Correspondence Schools, Scranton, Pa.
Mr. DUANE STUDLEY	{ Wabash College, Crawfords- ville, Indiana.

The following resolution was unanimously adopted by the consenting votes of the Directors, namely: Messrs. PIERSON, AITKEN, SEARES, ZIEL, PERRINE, KEELER, HILL, ST. JOHN, VON GELDERN, MOLERA, and Miss O'HALLORAN:—

Resolved, That, the amount of \$196.66 having been advanced by the General Fund to the Bruce Medal Fund, it is hereby ordered that said sum of \$196.66 be now transferred from the Life Membership Fund to the General Fund. This amount is to be refunded by the Bruce Medal Fund as soon as accrued interest is available for that purpose.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD IN THE ROOMS OF THE
SOCIETY, JANUARY 28, 1899, AT 8 P. M.

President AITKEN presided. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Is *Mars's* Axial Velocity Increasing? by Professor A. M. MATTOON.
2. The Constant of Attraction, by Mr. F. H. SEARIS.
3. Planetary Phenomena for March and April, 1899, by Professor MALCOLM MCNEILL.
4. The Story of the Sun, by Professor JAMES E. KEELER.

Professor KEELER's lecture on the Sun, illustrated by lantern-slides, was given in the lecture hall of the Academy, on Friday evening, January 27th.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 25th, was appointed as follows: Messrs. CHAS. S. CUSHING, JOHN DOLBEER, D. S. RICHARDSON, E. S. CLARK, A. S. BLAKE.

A committee to audit the accounts of the Treasurer and to report at the annual meeting was appointed as follows: Messrs. C. B. HILL, F. H. McCONNELL, O. VON GELDERN.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. R. G. AITKEN	President
Mr. C. B. HILL	First Vice-President
Miss R. O'HALLORAN	Second Vice-President
Mr. F. H. SEARES	Third Vice-President
Mr. C. D. PERRINE } Mr. F. R. ZIEL }	Secretaries
Mr. F. R. ZIEL	Treasurer
<i>Board of Directors</i> —Messrs. AITKEN, HILL, KEELER, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, SEARES, ST. JOHN, VON GELDERN, ZIEL.	
<i>Finance Committee</i> —Messrs. PIERSON, VON GELDERN, HILL.	
<i>Committee on Publication</i> —Messrs. AITKEN, SEARES, VON GELDERN.	
<i>Library Committee</i> —Messrs. SEARES, GEO. C. EDWARDS, Miss O'HALLORAN.	
<i>Committee on the Comet-Medal</i> —Messrs. KEELER (<i>ex-officio</i>), PIERSON, BURCKHALTER.	

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

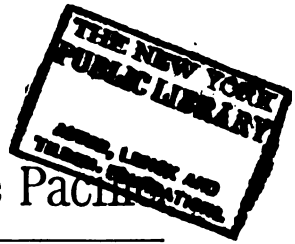
Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)



PUBLICATIONS
OF THE
Astronomical Society of the Pacific



VOL. XI. SAN FRANCISCO, CALIFORNIA, APRIL 1, 1899. No. 67.

ADDRESS OF THE RETIRING PRESIDENT OF THE
SOCIETY, IN AWARDING THE BRUCE MEDAL
TO GEH. RATH DR. ARTHUR AUWERS.

BY R. G. AITKEN.

In conformity with the statutes for the bestowal of the BRUCE Gold Medal of the Astronomical Society of the Pacific, the Board of Directors of the Society held a special meeting on the last Saturday of November, 1898, to consider the nominations for the award of the medal for the present year which were made by the Directors of the Berlin, Greenwich, Paris, Harvard, Yerkes, and Lick Observatories.

It becomes my pleasant duty this evening to announce to the Society that by the unanimous vote of the Board of Directors the award was made to Geheimer Rath Dr. ARTHUR AUWERS, of Berlin.

Dr. AUWERS's title to this mark of our consideration and respect may perhaps be most briefly stated in the words of our distinguished medalist of 1898. In his "Reminiscences of an Astronomer," in the *Atlantic Monthly*, Professor SIMON NEWCOMB says:—

"To-day, AUWERS stands at the head of German astronomy. In him is seen the highest type of the scientific investigator of our time, one perhaps better developed in Germany than in any other country. The work of men of this type is marked by minute and careful research, untiring industry in the accumulation of facts, caution in propounding new theories or explanations, and, above all, the absence of effort to gain recognition by being the first to make a discovery. When men are ambitious to figure as NEWTONS of some great principle, there is a constant temptation to publish unverified speculations which are likely rather

to impede than to promote the advance of knowledge. The result of AUWERS's conscientiousness is that, notwithstanding his eminence in his science, there are few astronomers of note whose works are less fitted for popular exposition than his. His specialty has been the treatment of all questions concerning the positions and motions of the stars. This work has required accurate observations of position, with elaborate and careful investigations of a kind that offer no feature to attract public attention, and only in exceptional cases lead to conclusions that would interest the general reader. He considers no work as ready for publication until it is completed in every detail, showing in this a conscientiousness which his fellow-astronomers may sometimes have reason to regret, owing to the length of time they have to wait for his conclusions."

These words from one who is himself in the front rank of the scientific investigators of our time offer reason enough for our award. At the same time, the strictly technical and theoretical character of Dr. AUWERS's work, to which Professor NEWCOMB calls attention, indicates the propriety of dwelling in more detail to-night upon the achievements of one who has done so much to advance and systematize our knowledge of the stars.

Born in Göttingen, on September 12, 1838, he entered the gymnasium of his native city, and was early attracted to the science of astronomy — probably through the influence of WINNECKE; for the latter, writing in 1854 of meteor observations made in July of that year by PAPE and himself, says that they were materially assisted on the first few nights by their young friend, Herr A. AUWERS (then a lad of sixteen). Later on, WINNECKE writes of a new nebula, found by Herr AUWERS in 1854.

Having decided thus early upon his life-work, we find him for the next few years continuing his university studies, and employing his leisure in observing variable stars, comets, asteroids, and nebulae, and in computing orbits and ephemerides of comets and asteroids.

In 1859, he became assistant astronomer at Königsberg, and for three years varied his theoretical studies by observations with the heliometer made famous by the work of BESSEL. In addition to valuable series of measures of comets, asteroids, nebulae, variable stars, and double stars, this resulted in an admirable series of observations for the parallax of certain stars, together with an exhaustive investigation of the instrument itself and a discussion of the methods of reduction of heliometer observations. It was with this instrument also, on May 21, 1860, that AUWERS, while observing variable stars, found the new star in Messier 80, the so-called *Nova Scorpii*.

In 1862, his inaugural dissertation for the degree of Doctor of Philosophy was published at Königsberg. This was the first part of his memoir on "Variable Proper Motions," and included an orbit of *Procyon* based on meridian observations. In this research he struck the key-note of his future life-work—"the treatment of all questions concerning the positions and motions of the stars."

Leaving Königsberg in the summer of 1862, Dr. AUWERS went to Gotha as assistant astronomer, and for some time continued his work at the observatory there under the guidance of P. A. HANSEN. In 1866, he was called to Berlin as the successor of ENCKE in the position of Secretary of the Royal Prussian Academy of Sciences, Section of Mathematics and Physical Sciences—a position he still holds. Since 1866, he has not, so far as I am aware, been officially connected with any observatory; but he has at times taken active part in the observing work at Berlin, at the Cape of Good Hope, and elsewhere, and has also held many positions which indicate the confidence his fellow-astronomers have in his administrative ability. Thus, he has repeatedly been President of the *Astronomische Gesellschaft*, was one of the first editors of the *Vierteljahrsschrift* of that Society, chairman of the commission in charge of the A. G. zone work, and chairman of the German Commission on the Transit of *Venus*.

Though a skillful and industrious observer, Dr. AUWERS is pre-eminently a theoretical astronomer, and his researches have been conducted, broadly speaking, toward the achievement of two main objects—(1) a better knowledge of the value of the solar parallax, and (2) the reduction of star-catalogues to a common fundamental system, so as to afford the means of utilizing readily all existing data in the accurate determination of the positions and motions of the fixed stars. Both investigations demand for their successful pursuit the highest order of skill, rare judgment, and a patience and an accuracy in the treatment of minute details that is given to but few minds. The comparison of star-catalogues and the formation of a fundamental system of star-places, for instance, involves careful consideration of the methods of observation and reduction used in every existing star-catalogue; of the values of the constants of precession, nutation, aberration, refraction, etc., adopted by each computer; of the nature and stability of the instruments used in the observations; of the systematic errors of observation due to the star's position and magnitude; of the per-

sonal equation of the observer; of the proper motions of the stars themselves;—in fact, of almost endless questions, hardly to be appreciated except by one engaged in similar investigations.

This problem was attacked by AUWERS, in a preliminary way, at an early age, as we know from the fact that in 1861 he published in *Astronomische Nachrichten*, at the instance of BRUHNS, FOERSTER, and others, the systematic corrections necessary to reduce a number of different catalogues to the system of the "Tabulæ Reductionum" of WOLFER's. These corrections he had been using, he says, for some time in determining the accurate positions of the comparison-stars for his observations of comets and asteroids.

A far more important step was taken in 1865, when he published his "Tables for the Reduction of the Declinations of Various Star Catalogues to a Fundamental System," and a few months later followed this with a discussion of the "Declinations of the Fundamental Stars." In these papers all existing material of value was carefully considered and the foundation laid for a homogeneous system of Declinations.

Meanwhile some special investigations suggested by this general problem had engrossed AUWERS's attention, as we see from the subject of his Inaugural Dissertation, viz: the variable proper motions of certain stars.

In 1844, BESSEL announced that, instead of moving at a uniform rate in a straight line, as do all other fixed stars with known proper motions, *Sirius* and *Procyon* showed evidences of variable motion—the former in Right Ascension, the latter in Declination; and in discussing the possible explanations of such motion, concluded that the only tenable hypothesis was that the bright star was the visible member of a binary system. In the case of the two stars under consideration, BESSEL did not feel that the observations then available warranted any more definite conclusion than that the motion was variable, and showed a period of about half a century.

In 1851, DR. C. A. F. PETERS repeated the investigation of the Right Ascensions of *Sirius*, confirmed BESSEL's conclusion of variable proper motion, and determined the orbit of the system with a revolution period of about fifty years. Ten years later, SAFFORD investigated the Declinations in a similar manner, and found the motion variable in this co-ordinate also, and showed that PETERS's orbit, which was based on Right Ascensions only,

would account for the motion in Declination with but small outstanding errors.

At this time AUWERS undertook a complete reinvestigation of this question with respect to both stars, examining with all possible care all the available observations in both Right Ascension and Declination, including in the case of *Sirius* 7,000 in Right Ascension and 4,500 in Declination. His results for *Procyon* were that the star revolved in a sensibly circular orbit in a period of about forty years. This part of the research formed, as has been said, his thesis for the Doctor's degree in 1862. His investigation of the motion of *Sirius* was published some two years later, and resulted in an orbit decidedly eccentric with a revolution period of fifty years. As is well known, this orbit for the theoretical companion was very accurately followed by the small attendant discovered by A. G. CLARK, in 1862. When the latter star was lost in the brilliant rays of its primary, in 1892, Dr. AUWERS again examined this system, taking into account the micrometer measures of the faint CLARK companion as well as the meridian observations of *Sirius* itself, and proved definitively that this companion accounted for the variable motion of the bright star first noticed by BESSEL.

In all of these investigations Dr. AUWERS had felt the need of a more accurate determination of the proper motions of stars than was possible from the catalogues then in existence. In such investigations BRADLEY's catalogue was by far the most important. Not only were his observations, for which the epoch was about 1755, the first that were at all comparable in system and accuracy with those of modern times, but they were also far superior to those of his successors for half a century or more, to the time of BESSEL and STRUVE.

These observations were first reduced in 1819, nearly fifty years after BRADLEY's death, by BESSEL, who indicated his estimate of their importance by the title, "*Fundamenta Astronomiæ.*" That this reduction was made by BESSEL is sufficient guaranty of its excellence; but in the half-century following its publication the rapid progress of astronomy in every line led to a more accurate knowledge of the fundamental constants, and to more refined methods of the reduction of meridian observations. It also became evident from PETERS's investigations in 1855 that some of BESSEL's assumptions respecting the transit instrument used by BRADLEY were erroneous.

As all these errors would seriously affect the proper motions derived from the BRADLEY stars, a new reduction was highly desirable, and this was undertaken in 1864, by WINNECKE, at Pulkowa. Illness, however, compelled him to give up the work; and in 1866 it was taken up by Dr. AUWERS. All his previous work had been fitting him for such a task, and the result was a "masterpiece and a model." AUWERS based his work upon specially collated copies of BRADLEY's original records, and spared no pains to insure the utmost accuracy in reduction. No detail was too minute, no computation too tedious, that might in any way improve the results.

In ten years this great task was substantially completed, and in 1877 the manuscript of the second volume, containing the individual observations in Right Ascension and Zenith Distance, was given to the printers. Four years were needed to get it through the press, and it was not distributed until 1882. A year later, on Dr. AUWERS's return from the Transit of *Venus* Expedition to Patagonia, the third volume was sent to the printer, but it was not distributed until 1888. This volume contains an extensive introduction and the catalogue proper. BRADLEY's star-places are given for the epoch 1755, and also for the epoch 1865. For the latter epoch a new catalogue of the same stars, based almost entirely upon Greenwich observations between 1854 and 1867, is also given by AUWERS, who determined the proper motions of the stars by comparing the two catalogues. The volume also contains all necessary data to reduce the stars to any desired epoch. The first volume will contain a number of special investigations connected with BRADLEY's work, and also the reduction of his observations of the planets. The manuscript was sent to the printer nearly three years ago, but the volume has not yet been issued.

In many respects this has been Dr. AUWERS's most important work, and as such it won for him the gold medal of the Royal Astronomical Society in 1888, and, in connection with his other work, the Watson gold medal of the National Academy of Sciences, of Washington, in 1891. In another sense, however, it is only another contribution towards the solution of the great problem of forming a homogeneous system of star-places, for it affords the means of a more accurate determination of the proper motions of the stars, and thus diminishes the difficulty of comparing catalogues of different epochs.

In the mean time an enterprise was inaugurated by the *Astronomische Gesellschaft* which promised the practical realization of a homogeneous star-catalogue, based not on existing observations, but upon a complete reobservation of the sky. At the meeting of the *Gesellschaft* in Leipzig, in 1865, Professor BRUHNS offered a resolution declaring that the *Astronomische Gesellschaft* considers it necessary that all stars to the ninth magnitude which are found in the Bonn D. M. be observed with meridian-circles, and commissions its Council to organize and superintend the execution of this work. The formulation of the preliminary plan was left to ARGELANDER, after considerable discussion. This plan, revised by a committee consisting of ARGELANDER, BRUHNS, and WINNECKE, was presented at the Bonn meeting of the Society in 1867. It limited the work to the stars lying between -2° and $+80^{\circ}$ Declination; provided that the observations should be differential, that every star should be observed at least twice; and suggested that the entire field be divided into zones extending over 5° or 10° in Declination. Each observatory that desired to share in the undertaking could then select the zone best suited to its location and equipment. This plan, in its essential features, was adopted, and various observatories volunteered to share in its execution. The list of fundamental stars, selected by ARGELANDER, was published the following year. These were to be accurately observed at Pulkowa.

This plan was modified in many of its details by the Council of the society, and the final form of the program to be followed was presented, for the Council, by Dr. AUWERS at the Vienna meeting, in 1869. The preparation of the fundamental catalogue of 539 stars was also left to Dr. AUWERS; so that what is now known as the A. G. system is, in one sense, AUWERS's system, and the catalogue of the *Astronomische Gesellschaft*, when completed, will be the practical realization of his endeavor to form a homogeneous catalogue of stars.

As one of the secretaries of the *Gesellschaft*, and later as chairman of the Zone Commission, Dr. AUWERS has had an active and influential part in the supervision of this work from its beginning. Not content with this, however, he gladly accepted Professor FOERSTER's offer to assist in observing the 10° zone set apart for the Berlin Observatory. The southern half of this zone — from $+15^{\circ}$ to $+20^{\circ}$ Declination — was put in his charge, and the

work begun early in 1869. The necessary observations — about 25,000 in number — were nearly all made before the end of 1871; but owing to the pressure of other work, especially the new reduction of the BRADLEY stars, Professor AUWERS did not press the work of reduction for some years. When he did take up this task, he extended his investigations to such bounds that the catalogue, which was finally issued in 1896, became really a comprehensive treatise on the positions and proper motions of the stars in the zone in question; for in addition to the catalogue proper the volume includes an elaborate comparison of the observed positions with all those found in previous catalogues, and from these comparisons a careful determination of the proper motions.

A few years after the adoption of the original plan, it was decided to extend the A. G. catalogue to the southern skies (to -23° Declination) as well, and the preparation of the necessary catalogue of southern fundamental stars was also intrusted to Dr. AUWERS.

As new material has become available through the highly accurate observations of the fundamental stars made in recent years with the best meridian-circles of our time, Dr. AUWERS has rediscussed and refined his fundamental catalogues. Still further to increase their practical convenience and usefulness as a standard of reference, he has also taken the time to construct extensive tables of systematic corrections for the reduction of nearly all existing catalogues of importance to the A. G. system.

These researches constitute Dr. AUWERS'S most important contributions to the progress of astronomy; but no inconsiderable portion of his scientific life has been devoted to the solution of the other problem I have mentioned — the more accurate determination of the value of the solar parallax.

In 1874, and again in 1882, elaborate preparations were made by astronomers to observe the transits of *Venus*, with the view of getting a better knowledge of this constant. There were many difficulties known to be inherent in this method; but astronomers at that time were not agreed upon any better one that was so independent of other constants, and it was hoped that the number of the independent observations and the variety of instruments used would give sufficient data to furnish a reliable conclusion.

Dr. AUWERS was placed in charge of one of the German expeditions in 1874 (to Luxor), and in 1882 had charge of the German expedition to Punta Arenas, Patagonia. Besides this, he was

chairman of the German Transit of *Venus* Commission, and in that capacity directed the general plan of observation for all the parties sent out by the German Government, and, later, had charge of the reduction of the results. These observations and their discussion are printed in an imposing series of volumes, of which Vols. II, III, IV, V, and VI have thus far been issued.

Needless to say, the work was planned with all possible care, and the discussion carried out with the thoroughness and accuracy which characterize all of Dr. AUWERS's work. But though the resulting value of the parallax constant is thus probably the best that can be attained by this method, — which is not likely to be tried again, — it appears from other considerations to be too large, and will be of little practical value in astronomical investigations.

Another method, first proposed by Professor GALLE, of Breslau, is free from many of the difficulties besetting the observation of the transit of *Venus*, and, as the event has shown, is the most accurate independent method yet tested. This consists in observing from different stations the displacement of the nearer asteroids among the stars at about the time of opposition. After some experiments, Dr. DAVID GILL, with the co-operation of Dr. AUWERS, and of Dr. ELKINS, of Yale, planned and executed an elaborate test of this method in 1888 and 1889 by concerted heliometer observations of the minor planets *Iris*, *Victoria*, and *Sappho*, at different observatories in the northern and southern hemispheres. Dr. AUWERS had a direct share in the observations themselves, going to the Cape of Good Hope to observe *Victoria* with Dr. GILL, in 1889.

The important work of constructing the catalogue of definitive positions of the comparison stars from the meridian observations, which had been especially instituted at a number of different observatories, was also intrusted to him. The final value of the solar parallax resulting from this investigation is undoubtedly the most accurate yet obtained, and is probably very near the truth.

This brief and imperfect account of Dr. AUWERS's contributions to the progress of the science to which he has devoted his life is utterly inadequate in its descriptions of the researches mentioned in it; and many others — minor indeed, comparatively speaking, but yet of great interest and value to astronomers — have not even been named. In spite of its incompleteness, however, enough, I think, has been said to show that Professor NEWCOMB's tribute, which I have quoted, is well deserved; and that

the trust placed in our Society by Miss BRUCE, to award this medal "for distinguished services to astronomy," has been kept in spirit as well as in letter, by our bestowal of it upon Geheimer Rath Dr. ARTHUR AUWERS.

In his necessary absence to-night, I hand the award to you, Mr. Secretary, to transmit to Dr. AUWERS, with the assurance of our appreciation of his great achievements, and the expression of our hope that, in the investigation of the many problems still waiting to be solved, his fellow-workers may long enjoy the advantage of his co-operation and counsel.

March 25, 1899.

SOME PHOTOGRAPHS OF THE GREAT NEBULA IN *ORION* WHICH ARE DIRECTLY COMPAR- ABLE WITH DRAWINGS.

By JAMES E. KEELER.

In an article printed several years ago in these *Publications*,* I considered at some length the effect of a supposed non-homogeneous structure of the nebulae on their forms as shown respectively in drawings and in photographs. The argument was briefly this: The nebula is seen by one set of rays, and photographed by a different set, so that the two different impressions cannot be expected to agree, unless these sets of rays are emitted in the same proportions by all parts of the nebula. The same considerations apply to any landscape; and it is only because the objects in a landscape have sharply defined outlines that the differences between the photograph and the view seen by the eye do not strike us more forcibly.

I do not by any means assert that the cause here mentioned is chiefly responsible for the differences between drawings and photographs of nebulae. These differences are no doubt mainly due to the nature of the object, and the extreme difficulty of drawing faint and diffuse forms. It is sufficiently obvious, moreover, to any one who looks over such a collection of drawings as Professor HOLDEN has brought together in his "Monograph on the Central Parts of the Nebula of *Orion*," that many of the

* Vol. VII, p. 279. (1895).

observers who tried to draw this object lacked the necessary skill with the pencil. Others scribbled a rough diagram, accentuating some feature that caught their attention. As a matter of fact, drawings differ among themselves quite as much as they differ from photographs.

However, if it can be shown that the spectrum of a nebula is not the same in all its parts, the cause which I have pointed out must be operative, and only the extent of its influence can be questioned. If the differences in the composition of the light, as revealed by the spectroscope, are considerable, some striking differences between drawings and photographs may be satisfactorily accounted for.

In the case of the *Orion* nebula, differences in the spectrum were suspected many years ago by Dr. HUGGINS, and later by Dr. HENRY DRAPER. Large differences were actually found and their amounts estimated in 1893 by Professor CAMPBELL. Some doubts which were expressed as to the reality of the observed appearances have been, I think, completely removed,* and it may be regarded as certain that the *Orion* nebula has by no means the fundamental sameness of constitution which has generally been ascribed to it; but that great differences exist in the relative strength of the lines in its spectrum.

The monochromatic images of the nebula produced by an object-glass prism have been photographed by Professor WM. H. PICKERING,† who showed that some slight differences in the spectrum of the Huyghenian region could be detected in this way. But this theoretically very beautiful method is practically far from satisfactory. The separate images thus obtained are feeble, so that only the brightest part of the nebula can be photographed; the images overlap, and are therefore confused; the many stars in the nebula are drawn out into spectra, and are no longer available as reference points; and the strong continuous spectra of the brighter stars overpower and practically obliterate the images of the nebula on which they are superposed.

In the article to which I have already referred, I suggested the use of a color-screen and orthochromatic plate for accomplishing the same purpose without any spectroscopic appliances; and I have recently been able to carry out the experiments there proposed, with the aid of the Crossley reflector — an instrument

* *A. N.*, 3541.

† *Annals H. C. O.*, Vol. XXXII, p. 74.

which possesses in the highest degree all the qualities required. The focal length of this telescope being nearly eighteen feet, the images are large; the ratio of focal length to aperture being about 6:1, the images are bright; the blue and violet rays of the spectrum are reflected with little loss; and there is no chromatic aberration such as affects the image formed by a refractor.

Two color-screens, of a yellowish-green color, were supplied by Mr. CARBUTT, the well-known dry-plate maker. The plates used were the Cramer "Isochromatic Instantaneous."

In order to understand just what is effected by the color-screen used in this way, it is necessary to consider the nature of the spectrum of the nebula, the selective absorption of the screen, and the sensitiveness of the orthochromatic plate to light of different wave-lengths.

The Spectrum of the Nebula.—If the spectrum of the brightest part of the nebula (the Huyghenian region) is examined with a spectroscope, three bright lines are at once seen. Two, about equally bright, are the $H\beta$ line of hydrogen and the line λ 4959. The lowest line, which is several times brighter than either of these, is the "chief" nebular line, λ 5007. The $H\gamma$ hydrogen line is also visible, but it is not at all bright, and a few other lines, due to helium and unknown substances, are visible under very favorable conditions. They contribute practically nothing to the brightness of the visual image seen in ordinary observation, which is almost entirely due to the lines first mentioned.

These three lines also appear on a photograph of the spectrum, taken on an ordinary plate; but their relative intensities are now quite different. The chief line is about as bright as $H\beta$, and λ 4959 is considerably weaker than either. Farther up in the spectrum are other and much stronger lines. Chief among these are $H\gamma$ and other lines of the hydrogen series, and a line at λ 3727, in the ultra-violet. There is also a number of weaker lines. The three lines which are seen in visual observation contribute little to the photographic image of the nebula.

If the spectrum is photographed on an orthochromatic instead of an ordinary plate, the appearance is nearly the same, but there is an important change in the relative intensities of the three lowest lines, which now nearly agree with the visual intensities. All three lines are, moreover, much stronger than before, as compared with lines in the upper spectrum.

Curve of Sensitiveness of an Orthochromatic Plate.—The sensitiveness of an ordinary dry plate is widely different for light of different colors. It may be conveniently represented by the height of a curve drawn above a map of the spectrum. Experiment shows that this curve rises gradually from the extreme ultra-violet to a maximum near the line $H\gamma$, from which it falls more abruptly toward $H\beta$. Without forced exposure (seldom possible in astronomical photography), it does not extend much beyond this line.

Isochromatic plates (notwithstanding their name) also vary greatly with respect to their sensitiveness to light of different colors. The curve of sensitiveness is, in its upper part, quite like that of an ordinary plate, having a maximum at $H\gamma$, but instead of ending it merely sinks to a minimum below $H\beta$, and then rises again to another, though lower, maximum in the yellow.

These properties of photographic plates explain the differences in the relative intensities of the three lowest nebular lines, which have already been described. The lowest line, which is brightest to the eye, does not affect an ordinary plate so strongly as the weaker line $H\beta$. On an orthochromatic plate, owing to the rise of the curve of sensitiveness toward the yellow, the brightest line is also photographically the strongest.

Selective Absorption of the Color-Screen.—The color-screens used in photography, like colored glasses in general, act by the absorption or suppression of certain kinds of light. The rays to which they owe their color are transmitted.

A color-screen, to be effective for the purpose now under consideration, must transmit the light of the three lowest nebular lines, and absorb all light of shorter wave-length. Since the nebular lines are in the green or bluish-green part of the spectrum, the color of the screen must be green.

It was found by visual and photographic observations of the solar spectrum, and also of the spectrum of hydrogen, that both the screens supplied by Mr. CARBUTT completely suppressed the ultra-violet, violet, and blue rays, the absorption extending down as far as $H\beta$. One of the screens, which has a strongly yellowish-green color, absorbs even the light in the region of the nebular lines to a considerable extent, and although the effect of this absorption was to render the photographed nebular lines more

nearly with their visual relative intensities, the screen had to be rejected, as the loss of light proved to be important. The other screen, which has a light-green color, was therefore chosen for the observations. Both screens, of course, strongly absorb the red, where their action is, however, immaterial in connection with the present investigation.

It will be seen from the foregoing considerations that when the spectrum of the nebula of *Orion* is photographed through the color-screen, on an orthochromatic plate, it is reduced to the three lines seen in visual observation, and that the visual relative intensities of these lines are approximately preserved. Hence a photograph of the nebula itself, taken in the same way, is directly comparable with the image of the nebula which is seen in the telescope in ordinary observation.

The Crossley reflector has a double-slide guiding apparatus of the form devised by Dr. COMMON. Small errors, due to irregular driving, changes of flexure, refraction, etc., are corrected by screws which move the plate-holder, the observer guiding by means of an eyepiece, with illuminated cross-wires, which is set on a star as close as possible to the edge of the ($3\frac{1}{4} \times 4\frac{1}{4}$) plate.

The color-screen was mounted immediately in front of the photographic plate, in a light frame which could easily be removed. On account of the large angular aperture of the reflector, the change of focus produced by the screen was quite perceptible, and had to be allowed for when the screen was inserted or removed.

With this apparatus a number of photographs of the *Orion* nebula were taken during the past winter, together with many photographs on ordinary plates, without the color-screen, for purposes of comparison. But it is not permissible to compare photographs taken by these two different methods without taking into account certain peculiarities of photographic action which have a great influence on the character of a negative. Every photographer knows that the densities of different parts of a negative are not by any means proportional to the different brightnesses of the objects which they represent. With lights of given intensity the relative density of the images, or amount of contrast, depends upon the length of exposure, quickness of the plate, manner of development, and other factors, and it can be made to vary within very wide limits. It is quite possible, for example, to reverse the order of brightness, so that the brighter

object shall give the weaker image. These facts depend on principles which are constantly taken advantage of in ordinary pictorial photography.

We may, however, safely assume, if we leave out of consideration certain cases not likely to occur in such investigations as these, that if all the conditions, including the quality of the light, have been the same, equally dense parts of the negative have been produced by equally bright parts of the object. Comparisons of some value can be made even on a basis no wider than this. But as I wished to draw conclusions from differences as well as from equality of density, efforts were made to obtain photographs, by the different methods, which should be directly comparable in this respect. What I aimed at, therefore, was to produce two photographs of the nebula on the same night, one taken on an ordinary plate and in the ordinary manner, the other taken on an orthochromatic plate through the color-screen, the exposures in the two cases being so timed that the two negatives, when placed in a tray and developed together, should develop in the same manner, and should appear equally dense when fixed. The conditions, as stated, apply to the Huyghenian region. On some occasions they were pretty nearly fulfilled.

For example, on February 9, 1899, an orthochromatic plate, protected by the color-screen, was exposed in the telescope for two hours and twenty minutes. The screen was then removed, the focus readjusted, and exposures of four, five, and six minutes, respectively, were given to three ordinary plates. The four plates were placed in a tray and developed together, when it was found that the four-minute plate and the orthochromatic plate developed with about equal rapidity, the Huyghenian region "coming up" in the same manner on both plates.

I had hoped that a moderate exposure through the color-screen would be sufficient to show a large amount of nebulosity, giving such a picture of the nebula as the eye would see if its sensitiveness could be greatly increased. But the first experiments showed that the photographic activity of the rays transmitted by the screen was so small that such a result could not possibly be obtained. This is evident from the example already given, the exposure in one case being thirty-five times that in the other.

However, the failure of the orthochromatic plate to show a great amount of nebulosity is not entirely caused by the insensitive-

ness of the plate to the nebular rays of low refrangibility. Comparing two plates taken in the manner described above, on which the Huyghenian region has the same density, I find that a much greater amount of nebulosity is shown on the ordinary dry plate. Conversely, if the two photographs show approximately the same amount of diffuse nebulosity, the Huyghenian region is very much stronger on the orthochromatic plate. This is the chief result of the investigation. It shows that, compared with the Huyghenian region, the nebular lines of the visual spectrum are faint, and the hydrogen lines strong, in the remote portions and outlying streamers of the nebula. Thus the spectroscopic observations made at Mt. Hamilton are confirmed, and the conclusions based on them extended to parts of the nebula which are beyond the reach of visual methods.

A valuable check on the comparisons is afforded by the numerous stars which are scattered through the nebula. These stars are presumably, like nearly all the stars in the same constellation, and particularly stars which are involved in the nebula, of the first spectral type, and rich in ultra-violet light. Their actinic power is therefore reduced by the screen in at least as great a ratio as that of the nebula. Hence if on plates with equally dense images of the Huyghenian region, taken by the two different methods, the stars appear in equal number and with equal strength (which is approximately the case), while the diffuse nebulosity is extremely weak on the one taken with the color-screen, the explanation can only be that which has already been given. Such is in fact the nature of the difference between plates compared in this manner.

The orthochromatic photographs, in giving great relative strength to the Huyghenian region, are evidently in accordance with drawings. Some more special results of the comparison of the two different kinds of photographs are given below.

Extending from the southeast corner of the Huyghenian region toward the south, is a long scimitar-like streamer which is visible in quite a small telescope. It was in fact discovered by MESSIER, as long ago as 1771. Close to it, on the west, and running parallel to it, is a shorter streamer, which is not easily visible, even in a large telescope. It is not shown in the drawings of HERSCHEL, Lord ROSSE, BOND, TROUVELOT, or in any of the drawings I have examined except one — the drawing made by LASSELL in 1862.

These two branches of the nebula are well shown in the photograph which forms the frontispiece of No. 66 of these *Publications*, and it will be observed that they have nearly the same intensity. Even with much shorter exposures, on ordinary plates, it is difficult to obtain an impression of the stronger branch without some indication of the existence of the weaker.

This discrepancy between celebrated drawings and photographs taken by the usual methods is explained at once by these investigations. The orthochromatic photographs and the drawings agree. On the plates taken with the color-screen the Messerian branch is strong and distinct, the companion only faintly visible. The inference is that in the spectrum of the former the lowest nebular lines are relatively strong, while in that of the latter the lines of hydrogen predominate.

The nebulosity surrounding the star Bond 734, north of the main nebula, is greatly weakened by the color-screen, a fact which shows that the less refrangible nebular lines are weak in this region, and confirms the spectroscopic observations made at Mt. Hamilton. The image photographed through the color-screen is no doubt almost entirely due to the light of the $H\beta$ line.

West of the nebula, ordinary photographs reveal some beautiful curves of nebulosity, with bright scalloped edges which are nearly as bright as the Messerian branch (see the frontispiece, No. 66). They are easily photographed with an exposure of two minutes. They are not visible, however, in the telescope, and of course are not shown on any drawing of the nebula. These bright curves of nebulosity are faintly shown on only one of my photographs taken with the color-screens. The explanation is the same as that which has been given for the other cases considered.

Some other differences are brought out by comparisons like these, but the above are the most interesting cases.

The photographs taken through the color-screen are not suitable for reproduction, on account of the great differences of density which they exhibit. I have therefore merely described the results obtained by comparing them with ordinary photographs, and have given the conclusions which I think one is justified in drawing from the comparison. In the photographic work at the telescope I had the efficient assistance of Messrs. E. F. CODDINGTON and H. K. PALMER, Fellows at the Lick Observatory.

The foregoing article contains, in somewhat more popular form, the substance of a paper contributed to the *Astrophysical Journal*.

LIST OF EARTHQUAKES IN CALIFORNIA FOR THE YEAR 1898.

COMPILED BY C. D. PERRINE.

The following list is a continuation of similar reports printed in these *Publications*, Vol. II, p. 74; Vol. III, p. 247; Vol. V, p. 127; Vol. VI, p. 41; Vol. VII, p. 99; Vol. VIII, p. 222; Vol. IX, p. 37; Vol. X, p. 64. A more complete account will be published by the United States Geological Survey as a bulletin. The dates are civil dates. The times are Pacific standard (120th meridian).

Roman numerals inclosed in parentheses indicate the intensity on the Rossi-Forel scale.

In 1898 twenty-four shocks of earthquake were recorded in California, a decrease of one as compared with 1897.

Two of the disturbances, viz., those of March 30th and April 14th, were very severe, comparable in intensity and damage with the worst shocks experienced here during the past half-century.

LIST OF EARTHQUAKE SHOCKS, 1898.

- January 1. Santa Rosa, 5 A.M.
- February 7. Mt. Hamilton, 0^h 38^m 3^s A.M., P. S. T., (I, II).
- March 7. Pacific Ocean, midway between Mazatlan and Hawaiian Islands, 10:12 P.M., G. M. T.
- March 17. Highland Springs, 0^h A.M.
- March 30. A severe shock in the central portion of the State, doing considerable damage to property. The center of the disturbance seems to have been in the vicinity of Vallejo and Mare Island. Mt. Hamilton, 11^h 42^m 22^s to 11^h 43^m 2^s P.M., P. S. T., (V) C. D. P. Heaviest shock at 11^h 42^m 45^s P. S. T., R. H. T. Berkeley, 11^h 42^m 26^s P.M., P. S. T.; Alameda, College Park, Carson City (Nevada), 11^h 45^m P.M.; Mills College, Antioch, Benicia, Bolinas, Colusa, Lodi, Martinez, Monterey, Pacific Grove, Del Monte, Modesto, Napa, Port Costa, Petaluma, Sonoma, Santa Cruz, St. Helena, Suisun, San Rafael, San Quentin, Sacramento, San José, Santa Rosa, Stockton, Vallejo, Walnut Creek.
- April 12. College Park, 4 P.M.

- April 14. San Francisco, 10:53, 11:07 P.M.; Oakland, Eureka, Mendocino, Little River, Point Arena, Greenwood, Ukiah, Fort Bragg, Berkeley, Mills College, 11:05 P.M.; Alameda, College Park, 11^h 10^m 39^s P.M. The center of this disturbance was on the coast near Mendocino City, and did some damage in the country about. The shock was distinctly felt in the Bay counties, but was not noticed at Mt. Hamilton.
- April 18. Prairie Camp (Mendocino County).
- April 25. Albion, Mendocino.
- April 26. College Park, 12:30 $\pm$ P.M.
- May 2. College Park, 6:02 A.M.; Salinas 6:05 A.M.; Santa Cruz.
- May 9. Gilroy, 7 A.M.
- May 20. Mt. Hamilton, 6^h 48^m 53^s $\pm$ $\frac{1}{2}$ ° A.M., P. S. T.; College Park, 6^h 49^m A.M.
- May 22. College Park, 11^h 15^m A.M.
- May 29. Santa Barbara, 7^h 03^m P.M.
- June 3. Los Olivos, 10^h 20^m P.M., Santa Barbara, 10^h 18^m P.M.
- June 8. Point Arena, 11:30 (A.M.), 1 (P.M.).
- June 30. Los Angeles, 11^h 26^m or 28^m P.M.
- July 19. Powder-mill explosion at Melrose, Alameda County, 5^h 20^m 47^s $\pm$ 2° A.M. Timed by Mr. A. H. BABCOCK.
- August 7. San Francisco, 11^h 57^m A.M.; Oakland, Berkeley, Alameda (?).
- August 12. Alameda, Mills College, 6^h 10^m A.M.
- August 19. Albion, 2:30 P.M. Reported by Mr. RALPH B. FUNK.
- October 27. Mt. Hamilton, 2^h 22^m 24^s or 25° P.M., P. S. T., (II).
- November 5. Mt. Hamilton, 9^h 9^m 8^s $\pm$ 5° P.M.
- November 19. Mt. Hamilton, 11^h 27^m 01^s A.M., (II).
- December 5. Heavy explosion at the powder-works at Pinole, Contra Costa County. Timed in San Francisco at 3^h 28^m 58^s P.M., P. S. T., by Mr. EVERETT HAYDEN, U. S. N.
- December 7. Alameda, 7^h 38^m 47^s P.M., P. S. T., (III or IV).
- The shocks at College Park were reported by Professor H. D. CURTIS; from Carson City, by Professor C. W. FRIEND.

MT. HAMILTON, CAL., 1899, February 18.

ELLIPTIC ELEMENTS OF COMET *b*, 1898 (PERRINE).

BY HEBER D. CURTIS.

From twenty-four observations by C. D. PERRINE, and one each by G. CISCATO and A. ANTONIAZZI, the following normal places were formed:—

	1898.	<i>a</i>			<i>δ</i>	Obs.
I.	March 22.0	21 ^h	25 ^m	48 ^s .47	18° 46' 28".2	7
II.	April 28.0	0	18	1.97	49 13 47.1	7
III.	June 6.0	3	31	35.99	56 17 15.9	6
IV.	July 19.0	5	34	7.35	53 31 34.1	6

From these places the following elements were computed:—

Perihelion, 1898, March 17.11895 G. M. T.

Epoch, March 20.0, 1898, G. M. T.

$$\begin{array}{l} M = 0^{\circ} \ 0' \ 25''.4 \\ \pi = 47 \ 18 \ 20.2 \\ \Omega = 262 \ 26 \ 3.6 \\ i = 72 \ 31 \ 55.8 \\ \phi = 78 \ 29 \ 56.2 \end{array} \left. \vphantom{\begin{array}{l} M \\ \pi \\ \Omega \\ i \\ \phi \end{array}} \right\} 1898.0$$

Period 402.789 years.

$$\log a = 1.736718$$

$$\log q = 0.039459$$

$$\log e = 9.991191$$

$$\log \mu = 0.944929$$

Residuals for the middle places (C — O):—

$$\begin{array}{ll} \Delta \lambda' = + 0''.2 & \Delta \beta' = + 2''.3 \\ \Delta \lambda'' = 0.0 & \Delta \beta'' = - 1.4 \end{array}$$

Constants for the equator of 1898.0:—

$$x = r [9.512398] \sin (23^{\circ} 26' 14''.2 + v)$$

$$y = r [9.999996] \sin (292 \ 43 \ 47.5 + v)$$

$$z = r [9.975703] \sin (22 \ 38 \ 46.0 + v)$$

COLLEGE PARK, February, 1899.

OBSERVATIONS OF *MIRA* (*o Ceti*). 1898–99.

BY ROSE O'HALLORAN.

As cloudiness prevailed during the summer nights for several successive weeks, satisfactory observations of this variable were:

not obtained until September 9th, since which date more than ninety estimates of its comparative brightness were made, an opera-glass or a four-inch telescope being used when required.

The general result is conveyed in the following data :

September 9, 1:30 A.M. Equal to γ *Ceti*.

September 18, 11 P.M. Brighter than γ .

September 22, 11 P.M. About midway between α and γ *Ceti*.

September 28, 10:30 P.M. One fourth less than α *Ceti*.

October 4, 2 A.M. Near the meridian the stars seem alike in tint and brightness, though the variable has the lower altitude.

This is the highest magnitude it has attained during the maxima of the last five years.

October 12, 4:30 A. M. Slightly dimmer than α .

October 16. Ditto, with equal altitudes and a clear, dark sky.

October 25. The difference has gradually increased, and it is now about one fourth dimmer than α .

November 1. Midway between α and γ *Ceti*.

November 11. It is one fourth brighter than γ *Ceti*.

November 15. In its decreasing stage it again equals this star, classed as nearly of third magnitude.

November 21. In hazy moonlight seems less than γ .

November 28. Midway between γ and δ *Ceti*.

December 3. Equal to δ .

December 8. Half a magnitude less than δ .

December 13. Equal to XI *Piscium* of fifth magnitude, which has a similar reddish tint.

December 18. Barely discernible to the naked eye, but slightly brighter than 69 *Ceti*.

December 26 Still brighter than 69, 70, and the other adjacent stars of sixth magnitude.

January 2, 1899. Equal to 69 *Ceti*.

January 5. Not equal to 69, but brighter than 71 *Ceti*.

January 19. After two weeks of cloudy nights the variable was found to be dimmer than 71 *Ceti*.

January 25. About half a magnitude less than 71.

January 29. Equal to an adjacent star of eighth magnitude.

February 6. Midway between eighth and ninth magnitude according to the D. M. stars in vicinity.

February 18. No noticeable decrease.

March 4. Still of 8.5 magnitude. After this date satisfactory observations were not obtained.

This is the first time for several years that it has been possible to observe the decline to eighth magnitude of this wonderful star. It is of interest to note the unevenness of the pace at which it varied. In its ascending stage it took only twenty-five days to increase from the luster of γ *Ceti* to that of α *Ceti*; but in the process of decline forty-two days were required to sink to equality with the lesser star. When the maximum was past, there was no revival of lost light, except what may be attributed to atmospheric causes; but the decline from fourth to fifth and from seventh to eighth magnitude was more rapid than the intervening variations.

SAN FRANCISCO, March 11, 1899.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1899.

BY PROFESSOR MALCOLM MCNEILL.

MAY.

Mercury is a morning star throughout the month, and comes to its greatest western elongation on May 9th. The planet is then near its aphelion, and the apparent distance, 26° , is quite large, but since the planet is about 10° south of the Sun the interval between the rising of the planet and sunrise will be only about an hour, and *Mercury* cannot be seen except under very good weather conditions during the first half of the month.

Venus is a morning star, and throughout the month rises about $1^h 20^m$ before sunrise. It is moving eastward and northward through the constellation *Pisces* into *Aries* with a velocity just a little greater than that of the Sun's apparent motion among the stars, the total distance traversed being about 35° .

Mars still remains in good position for evening observation, and does not set until after midnight until nearly the end of the month. During the month it moves about 15° eastward and 5° southward from the constellation *Cancer* into *Leo*, from a position near γ *Cancr*i to a position 5° west and 3° north of *Regulus*, the brightest star in *Leo*. Its actual distance from the Earth keeps on increasing at the rate of over 20,000,000 miles per month, and it is losing constantly in brightness.

Jupiter is in good position for observation, being well above the horizon at sunset, and not setting until long after midnight. It is in the constellation *Libra*, and moves westward and northward about 3° during the month. At the end of the month it lies about half-way between *Libra* and *Spica* (*a Virginis*).

Saturn is gradually getting into position for evening observation, and rises during the evening twilight at the end of the month. It is in the southern part of *Ophiuchus*, near *Scorpio* and *Sagittarius*, and moves about 2° westward during the month.

Uranus is in opposition with the Sun on May 27th, and is above the horizon during the entire night at that time. It is in the constellation *Scorpio*, 5° north of the first-magnitude star, *Antares*, and moves about 1° westward during the month.

Neptune is in the eastern part of *Taurus*.

JUNE.

Eclipses. The first is a *partial eclipse of the Sun* on June 8th. It will be visible in Europe and throughout the regions not too far from the North Pole, including Alaska, where the eclipse occurs at about sunset of June 7th.

The second is a *total eclipse of the Moon*. It will not be visible in the eastern part of the United States, but the beginning of it may be seen in the far west a little before sunrise on June 23d.

Mercury is a morning star at the beginning of the month, too near the Sun to be seen. It rapidly nears the Sun, passes superior conjunction on June 14th, and becomes an evening star. Its distance from the Sun increases rapidly, and by the end of the month it is far enough away so that it can be seen in the evening twilight.

Venus still keeps up its eastward motion just a little faster than the Sun's, and rises less than an hour and a half before sunrise. It moves from *Aries* nearly through *Taurus*.

Mars is gradually drawing nearer the Sun in apparent position, and is no longer a conspicuous object. It moves 16° eastward and 6° southward through the constellation *Leo*, and on June 12th passes less than 1° north of *Regulus*, the principal star of the constellation. At the end of the month its distance from the Earth is 176,000,000 miles, and its light will be only about one ninth of what it was at opposition.

Jupiter does not set until after midnight. It is in the constel-

lation *Libra*, and moves westward 1° until June 27th, when it begins to move eastward.

Saturn rises about sunset, and can be seen throughout the entire night. It is in opposition with the Sun on June 11th. It is in the extreme southern part of *Ophiuchus*, and moves westward about 2° .

Uranus is about an hour's motion ahead of *Saturn*, is in the constellation *Scorpio*, and moves westward about 1° . It is 5° north and west of *Antares*, and 3° east and $1\frac{1}{2}^{\circ}$ south of β *Scorpii* at the end of the month.

Neptune is in conjunction with the Sun on June 15th.

PHASES OF THE MOON, P. S. T.

			H. M.			H. M.
Last Quarter,	May 2,	9 47 A. M.				
New Moon,	May 9,	9 39 A. M.		June 7,	10 20 P. M.	
First Quarter,	May 17,	9 13 A. M.		June 16,	1 46 A. M.	
Full Moon,	May 24,	9 49 P. M.		June 23,	6 20 A. M.	
Last Quarter,	May 31,	2 55 P. M.		June 29,	8 45 P. M.	

THE SUN.

1899.	R. A. H. M.	Declination. ° /	Rises. H. M.	Transits. H. M.	Sets. H. M.
May 1.	2 34	+ 15 6	5 5 A. M.	11 57 A. M.	6 49 P. M.
11.	3 12	+ 17 54	4 53	11 56	6 59
21.	3 52	+ 20 12	4 44	11 56	7 8
June 1.	4 37	+ 22 4	4 39	11 58	7 17
11.	5 18	+ 23 6	4 35	11 59	7 23
21.	5 59	+ 23 27	4 36	12 1 P. M.	7 26
July 1.	6 41	+ 23 7	4 40	12 4	7 28

MERCURY.

May 1.	1 6	+ 4 26	4 15 A. M.	10 30 A. M.	4 45 P. M.
11.	1 36	+ 6 32	3 57	10 19	4 41
21.	2 23	+ 11 14	3 48	10 27	5 6
June 1.	3 35	+ 17 53	3 52	10 55	5 58
11.	5 0	+ 23 11	4 17	11 41	7 5
21.	6 35	+ 24 55	5 5	12 37 P. M.	8 9
July 1.	7 59	+ 22 30	6 1	1 22	8 43

VENUS.

May 1.	0 22	+ 0 38	3 43 A. M.	9 45 A. M.	3 47 P. M.
11.	1 6	+ 5 8	3 33	9 50	4 7
21.	1 51	+ 9 32	3 23	9 56	4 29
June 1.	2 42	+ 14 0	3 15	10 3	4 51
11.	3 30	+ 17 32	3 10	10 11	5 12
21.	4 20	+ 20 20	3 10	10 22	5 34
July 1.	5 11	+ 22 16	3 14	10 34	5 54

MARS.

May 1.	8 39	+	20 32	10 48 A.M.	6 1 P.M.	1 14 A.M.
11.	8 58	+	19 6	10 34	5 41	12 48
21.	9 17	+	17 29	10 20	5 21	12 22
June 1.	9 40	+	15 31	10 6	5 0	11 54 P.M.
11.	10 0	+	13 34	9 54	4 41	11 28
21.	10 21	+	11 28	9 44	4 23	11 2
July 1.	10 43	+	9 13	9 33	4 5	10 37

JUPITER.

May 1.	14 11	—	11 43	6 12 P.M.	11 32 P.M.	4 52 A.M.
June 1.	13 59	—	10 40	3 55	9 18	2 41
July 1.	13 55	—	10 27	1 52	7 16	12 40

SATURN.

May 1.	17 30	—	21 47	10 13 P.M.	2 55 A.M.	7 37 A.M.
June 1.	17 22	—	21 40	8 2	12 45	5 28
July 1.	17 13	—	21 33	5 50	10 33 P.M.	3 16

URANUS.

May 1.	16 21	—	21 23	9 3 P.M.	1 46 A.M.	6 29 A.M.
June 1.	16 16	—	21 11	6 51	11 35 P.M.	4 19
July 1.	16 11	—	20 59	4 47	9 32	2 17

NEPTUNE

May 1.	5 29	+	22 0	7 33 A.M.	2 52 P.M.	10 11 P.M.
June 1.	5 34	+	22 4	5 36	12 55	8 14
July 1.	5 39	+	22 7	3 37	10 57 A.M.	6 17

ECLIPSES OF JUPITER'S SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

	H.	M.		H.	M.
III, R,	May 2.	10 11 P.M.	I, R,	June 4.	3 58 A.M.
II, R,	4.	9 42	I, R,	5.	8 27 P.M.
I, R,	4.	11 53	II, R,	5.	9 29
I, R,	6.	6 22	III, R,	7.	6 2
III, R,	10.	2 9 A.M.	I, R,	12.	10 21
II, R,	12.	12 19	II, R,	13.	12 7 A.M.
I, R,	13.	3 15 P.M.	III, D,	14.	8 31 P.M.
II, R,	19.	2 56 A.M.	III, R,	14.	10 0
I, R,	20.	10 10 P.M.	I, R,	20.	12 15 A.M.
I, R,	28.	12 4 A.M.	I, R,	21.	6 44 P.M.
I, R,	29.	6 32 P.M.	III, D,	22.	12 30 A.M.
II, R,	29.	6 52	I, R,	28.	8 39 P.M.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

COMET SWIFT *a* 1899.

About midnight, March 3d, a telegram was received at the Lick Observatory from Dr. LEWIS SWIFT, of the Lowe Observatory, Echo Mountain, announcing his discovery of a new comet, which he described as large, very bright, and having a short tail. From my observations on the three following nights, I have computed the elements of the orbit given below. According to these elements the motion of the comet is retrograde, and in a short time its apparent place will be so near the Sun as to render observations of it impossible. After passing perihelion it will be north of the ecliptic, and its position with reference to the Earth and Sun will be such that it may readily be observed in the northern hemisphere after the early part of May. At discovery it was just visible to the naked eye, and in May its theoretical brightness will be about the same. It may be remembered, however, that shortly after perihelion passage the brightness of comets frequently exceeds that given by theory, and especially so when they have passed very near the Sun. The perihelion distance of this comet is about 32,000,000 miles. This is not a very small distance, yet is much less than the average, which for the 303 cometary apparitions of this century is about 87,000,000 miles.

At the time of my first observation of Comet Swift, it had a well-defined nucleus of about the tenth magnitude, a large coma, six or eight minutes of arc in diameter, which was very diffuse at the edges, and a slight indication of a tail. Since then the central part of the comet has changed somewhat in appearance. The nucleus is not so distinctly stellar; it appears rather as the

* Lick Astronomical Department of the University of California.

point towards which the coma increases rapidly in density and brightness. At the later observations the tail also has been more definite in form and of greater length.

ELEMENTS.

$$\begin{aligned} T &= 1899 \text{ April } 13.26427, \text{ Gr. M. T.} \\ \omega &= 4^{\circ} 54' 14''.4 \\ \Omega &= 23 \quad 8 \quad 45 \quad .2 \\ i &= 146 \quad 3 \quad 42 \quad .6 \end{aligned} \left. \vphantom{\begin{aligned} T \\ \omega \\ \Omega \\ i \end{aligned}} \right\} 1899.0$$

$$\log q = 9.537504.$$

$$\Delta\lambda' \cos \beta' = + 3''.0 \quad \Delta\beta' = - 4''.9$$

W. J. HUSSEY.

A NEW STAR IN *SAGITTARIUS*.

From an examination of the Draper Memorial photographs, Mrs. FLEMING has discovered a new star in the constellation *Sagittarius*. Its position for 1900 is R. A. $18^h 56^m.2$; Decl. $- 13^{\circ} 18'$. It was too faint to be photographed on eighty plates taken between October 18, 1888, and October 27, 1897, although stars as faint as the fifteenth magnitude appear on some of them. It appears on eight photographs taken while it was bright. On March 8, 1898, it was of the fifth magnitude, and on April 29, 1898, of the eighth magnitude. A plate taken this morning (March 9, 1899) shows that the star is still visible, and is of the tenth magnitude. Two photographs show that its spectrum resembles those of other new stars. Fourteen bright lines are shown, six of them due to hydrogen.

The entire number of new stars discovered since 1885 is six, of which five have been found by Mrs. FLEMING.

HARVARD COLLEGE OBSERVATORY,
March 9, 1899.

E. C. PICKERING.

COMMUNICATION CONCERNING THE PUBLICATION OF AN
ANNUAL ASTRONOMICAL REPORT.

I intend to publish an "Astronomischer Jahresbericht mit Unterstützung der Astronomischen Gesellschaft" (Astronomical Yearly Report aided by the Astronomische Gesellschaft). It will give short reports of all the works on astronomy, astrophysics, and geodesy, both practical and theoretical, which have appeared

during the year. The first volume will appear in 1900, and will contain reports of all the publications of 1899. Not wishing to overlook anything, I should be much obliged if all authors of such publications, appearing as single books or articles in journals not usually destined and used for astronomical publications, would kindly communicate them to me.

WALTER F. WISLICENUS, Ph. D.,
Professor at the University.

STRASSBURG (ELSASS), Nicolausring 37.
January, 1899.

ASTRONOMICAL TELEGRAMS.

(*Translations.*)

CAMBRIDGE, Mass., March 3, 1899.

To Lick Observatory: (Received 9:50 P.M.)

Kiel cables asking Lick please to look for TUTTLE's periodic comet.* Please telegraph any observation.

(Signed) EDWARD C. PICKERING.

LOWE OBSERVATORY, Echo Mt., Cal., March 3, 1899.

To Lick Observatory: (Received 12:00 P.M.)

Comet in R. A. $3^h 45^m$; Decl. -29° . Large, very bright, short tail.

(Signed) LEWIS SWIFT.

BOSTON, Mass., March 4, 1899.

To Lick Observatory: (Received 12:38 P.M.)

SWIFT announces bright naked-eye comet. R. A. $3^h 45^m$; Decl. -29° . Short tail, slow.

(Signed) JOHN RITCHIE, JR.

MT. HAMILTON, March 4, 1899.

To Harvard College Observatory: (Sent 10:02 P.M.)

Comet Swift was observed by W. J. HUSSEY on March 4.6356 G. M. T. in R. A. $3^h 48^m 4^s.3$; Decl. $-27^\circ 7' 52''$.

MT. HAMILTON, March 6, 1899

To Harvard College Observatory: (Sent 10:30 A.M.)

Comet Swift was observed by W. J. HUSSEY on March 5.6478 G. M. T. in R. A. $3^h 42^m 12^s.6$; Decl. $-25^\circ 36' 54''$.

* The search ephemeris given in this telegram is here omitted.

MT. HAMILTON, March 6, 1899.

To Harvard College Observatory: (Sent 9:23 P.M.)

Comet Swift was observed by W. J. HUSSEY on March 6.6523 G. M. T. in R. A. $3^h 36^m 44^s.5$; Decl. $- 24^\circ 8' 32''$.

CAMBRIDGE, Mass., March 7, 1899.

To Professor JAMES E. KEELER: (Received 6 P.M.)

Kiel cables that a faint comet was discovered by WOLF on March 5.325 G. M. T. in R. A. $1^h 16^m$; Decl. $+ 31^\circ 38'$. Daily motion in R. A. $+ 56'$; in Decl. $- 14'$. Probably TUTTLE's periodic comet. (Signed) EDWARD C. PICKERING.

CAMBRIDGE, Mass., March 7, 1899.

To Lick Observatory: (Received 9:07 P.M.)

DAVIS telegraphs that Comet Swift was observed by BROWN [at Washington], on March 5.5467 G. M. T. in R. A. $3^h 42^m 46^s.9$; Decl. $- 25^\circ 45' 49''$. EDWARD C. PICKERING.

MT. HAMILTON, March 8, 1899.

To Harvard College Observatory: (Sent 12:08 P.M.)

Comet Wolf was observed by C. D. PERRINE on March 7.6569 G. M. T. in R. A. $1^h 24^m 51^s.3$; Decl. $+ 31^\circ 7' 14''$.

MT. HAMILTON, March 8, 1899.

To Harvard College Observatory: (Sent 4:51 P.M.)

Elements and ephemeris* of Comet α (Swift) were computed by W. J. HUSSEY, as follows:

$T =$ G. M. T. April 13.26.

$$\left. \begin{array}{l} \omega = 4^\circ 54' \\ \Omega = 23 \quad 9 \\ i = 146 \quad 4 \end{array} \right\} 1899.0$$

Natural $q = 0.3447$.

CAMBRIDGE, Mass., March 9, 1899.

To Professor JAMES E. KEELER: (Received 5:00 P.M.)

Kiel cables a corrected ephemeris* for Comet Tuttle, which was computed by J. RAHTS.

(Signed) EDWARD C. PICKERING.

* The ephemeris is here omitted.

AWARD OF THE GOLD MEDAL OF THE ROYAL ASTRONOMICAL SOCIETY.

At the anniversary meeting of the Royal Astronomical Society on Friday last [February 10, 1899] Mr. FRANK McCLEAN, F. R. S., was awarded the Gold Medal of the Society for his photographic survey of stars in both hemispheres, and other contributions to the advancement of astronomy.—*Nature*.

A NEW SATELLITE OF SATURN.

A new satellite of the planet *Saturn* has been discovered by Professor WILLIAM H. PICKERING, at the Harvard College Observatory. This satellite is three and a half times as distant from *Saturn* as *Iapetus*, the outermost satellite hitherto known. The period is about seventeen months, and the magnitude fifteen and a half. The satellite appears upon four plates taken at the Arequipa Station with the Bruce photographic telescope. The last discovery among the satellites of *Saturn* was made half a century ago, in September, 1848, by Professor GEORGE P. BOND, at that time Director of the Harvard College Observatory.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

March 17, 1899.

A LABORATORY MANUAL IN ASTRONOMY. By MARY E. BYRD, A. B., Director of the Observatory, Smith College. Ginn & Co. Boston, IX + 273 pp. \$1.35.

The title of this little book indicates very accurately its aim and scope. It lays no claim to the name of a text-book in astronomy, and gives practically no definitions of astronomical terms nor descriptions of the usual appliances of a working observatory. It is designed to be used in connection with a standard text-book (like YOUNG'S or NEWCOMB'S), in precisely the same manner as a laboratory manual in chemistry or in physics would be used—to suggest, outline, and illustrate experiments to be performed by the student himself.

In her preface the author says: "Whether the study of astronomy is taken up first in secondary schools or colleges, years of experience have convinced me that it is best to devote at least one term to general astronomy and naked-eye observa-

tion. An unobstructed place for watching the heavens, a few home-made instruments, and evening hours of laboratory instruction will, I believe, do more to foster a genuine interest in astronomy or prepare for the use of instruments of precision than any amount of text-book study which is supplemented only by desultory star-gazing."

The book has thus grown out of the author's own experience and the needs of her students, and will commend itself to any one who has attempted to teach astronomy to beginners as eminently practical.

The suggestions for beginners in the introductory chapter, respecting the working-list, personal bias, errors, weights, rules for recording, etc., are admirably stated, and may be read and heeded with profit by some who are not beginners. The second chapter describes some simple home-made instruments, and gives directions for their adjustment and use. Then follow chapters on almanacs and maps, celestial globe, and heliotellus, the Sun, the Moon, planets, comets, and shooting stars, stars and Milky Way, and finally a chapter on observations for an inch-and-a-half telescope, and several useful appendixes. In all these chapters a list of suggestive exercises or questions comes first, the answers to which are to be worked out by the students themselves from direct observations or the data furnished by observation.

These exercises have evidently been selected very judiciously, and the suggestions and illustrations that occupy the remaining part of each chapter contain sufficient information to make the book a useful one to an intelligent student, even without the aid of a teacher. One who has worked through it carefully will have a practical grasp of the objects and methods of astronomical work that can be gained so easily in no other way, and will be well prepared to begin work with the ordinary instruments of precision of the observatory.

R. G. A.

March 1, 1899.

ERRATA IN APPENDIX OF AMERICAN EPHEMERIS FOR 1900.

The obliquity of the ecliptic, as given in the Appendix "On the Construction of the American Ephemeris and Nautical Almanac for 1900," is three degrees in error, being this amount too small. On the same page (p. 541) the adopted semi-diameter of the Sun is one minute too large.

W. J. HUSSEY.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF
DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE
PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON
SATURDAY, NOVEMBER 26, 1898, AT 2 P.M.

Mr. AITKEN presided. A quorum was present.

The purpose of the meeting being the Second Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

SAN FRANCISCO, November 26, 1898.

SECOND AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at 2 o'clock P.M., for the purpose of awarding the medal for the year 1899; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

ARTHUR AUWERS,

for Distinguished Services to Astronomy, by the consenting votes of eight Directors.

Signed: R. G. AITKEN, C. M. ST. JOHN, ROSE O'HALLORAN,
WM. M. PIERSON, FREDERICK H. SEARES, C. D. PERRINE (by proxy),
JAMES E. KEELER (by proxy), F. R. ZIEL.

In response to a request made by one of the nominating Observatories, the Board of Directors A. S. P. construes the provision in Article V of the Statutes, referring to "Astronomers worthy to receive the medal for the ensuing year," to cover services rendered during the lifetime of the nominee.

Adjourned.

On January 1, 1899, the Secretary addressed a letter to Professor AUWERS, notifying him of the action taken by the Directors. The following letter of acceptance was received on February 21st:—

(Translation)

Mr. F. R. ZIEL, *Secretary*,

BERLIN, January 31, 1899.

Dear Sir: I am in receipt of your communication of the 1st inst., in which you notify me of the award of the Bruce Medal of the Astronomical Society of the Pacific.

The regulations, which the founder (who has done so much for astronomy) has, with wise foresight, established for the bestowal of this medal, make the award a high honor for the recipient.

I feel very much gratified that my efforts to serve the Science have been found worthy of this recognition, and it is a special gratification for me to now share this honor with your eminent Professor NEWCOMB.

I request you to transmit to the Directors of your Society my sincere and grateful thanks for the distinction thus conferred upon me.

Yours most respectfully,

Signed: A. AUWERS.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 25, 1899, AT 7:30 P.M.

President AITKEN presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 25, 1899.

Astronomical and Physical Observatory, Taschkent, Turkestan, Russia.
Mr. J. BASSETT { 82 High St., Stoke Newington N.
London, England.
Mr. W. EDWARDS 1519 Eddy St., S. F., Cal.
Mr. C. F. HARMS 140 Broad St., New York, N. Y.
Library of the Minneapolis Athenæum. Minneapolis, Minn.
Prof. WILLETT C. PIERSON { 611 Prospect Place, Avondale,
Cincinnati, Ohio.
Mr. ALFRED DE VERVINS { 3923 Delmar Boulevard, St.
Louis, Mo.

The Library Committee presented its report, as follows, and the report was, on motion, adopted and filed:—

REPORT OF THE COMMITTEE ON THE LIBRARY, SUBMITTED MARCH 25, 1899.

To the Board of Directors of the Astronomical Society of the Pacific:

GENTLEMEN—We, the undersigned, Committee on the Society's Library, respectfully report as follows:—

During the past year 132 volumes, not including unbound books and pamphlets, have been added to the shelves of the library by gift, purchase, and binding. The total number of volumes in the library, as shown by the accessions book, is at present 1042.

A complete card-index has been constructed for bound volumes, and the Committee would recommend that as soon as practicable this index be extended so as to include the unbound volumes and pamphlets.

The following is an account of the expenditures of the Alexander Montgomery Library Fund for the year ending March 25, 1899:—

1898, May 31.	Hicks-Judd Co., for binding 24 vols.	\$15 45
Aug. 16.	<i>Popular Astronomy</i>	2 50
Oct. 14.	<i>Astronomical Journal</i> , Vols. V and VI	9 00
Dec. 31.	Stamps, telephoning, car-fare, for Librarian.	5 00
1899, Mar. 14.	Books and pamphlets from the library of E. S. HOLDEN, @ one-half bookseller's prices.	70 10
Mar. 14.	Young's <i>General Astronomy</i> , new edition.	2 25

\$104 30

Respectfully submitted,

F. H. SEARES, *Librarian*,
GEO. C. EDWARDS,
ROSE O'HALLORAN.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL
SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE
SOCIETY, MARCH 25, 1899, AT 8 P.M.

The meeting was called to order by President AITKEN. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Address of the retiring President of the Society in Conferring the Bruce Medal upon Geh. Rath Dr. ARTHUR AUWERS, by R. G. AITKEN.
2. Reports of Committees: on Nominations; on the Comet-Medal; on Auditing; and Annual Report of the Treasurer.
3. Photographs of the Great Nebula in *Orion* which are Comparable with Drawings, by JAMES E. KEELER.
4. Observations of *Mira (a Ceti)* in 1898-99, by ROSE O'HALLORAN.
5. Elliptic Elements of Comet I, 1898 (Perrine), by H. D. CURTIS.
6. Earthquakes in California in 1898, by C. D. PERRINE.
7. Planetary Phenomena for May and June, 1899, by M. McNEILL.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. CHAS. BURCKHALTER, W. W. CAMPBELL, C. B. HILL, J. E. KEELER, E. J. MOLERA, GEO. C. PARDEE, C. D. PERRINE, WM. M. PIERSON, O. VON GELDERN, F. R. ZIEL, and Miss R. O'HALLORAN.

For Committee on Publication: Messrs. R. G. AITKEN, S. D. TOWNLEY, O. VON GELDERN.

Messrs. BURCKHALTER and PALMER were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED
MARCH 25, 1899.

This report relates to the calendar year 1898. The comets of 1898 have been:

- Comet *a* (periodic comet) 1892 IV (Winnecke), re-discovered by Mr. C. D. PERRINE, Assistant Astronomer at the Lick Observatory, on the morning of January 2d.
- Comet *b* (unexpected comet), discovered by Mr. C. D. PERRINE, Assistant Astronomer at the Lick Observatory, on the morning of March 20th.
- Comet *c* (unexpected comet), discovered (photographically) by Mr. E. F. CODDINGTON, Fellow at the Lick Observatory, on June 11th. Independently discovered by Herr W. PAULY, of Bukarest, on June 14th.
- Comet *d* (periodic comet) 1895 I (Encke), re-discovered by Mr. JOHN GRIGG, of Thames, New Zealand, on June 7th, and independently by Mr. JOHN TEBBUTT, of Windsor, New South Wales, on June 12th.

Comet *e* (unexpected comet), discovered by Mr. C. D. PERRINE, Assistant Astronomer at the Lick Observatory, on the morning of June 15th.

Comet *f* (periodic comet) 1891 II (Wolf), re-discovered by Professor W. J. HUSSEY, Astronomer of the Lick Observatory, on June 16th.

Comet *g* (unexpected comet), discovered by M. E. GIACOBINI of the Nice Observatory, on June 18th.

Comet *h* (unexpected comet), discovered by Mr. C. D. PERRINE, Assistant Astronomer at the Lick Observatory, on the morning of September 13th. Independently discovered by M. P. CHOFARDET, of Besançon, on the morning of September 15th.

Comet *i* (unexpected comet), discovered by Dr. WM. R. BROOKS, of Smith Observatory, Geneva, N. Y., on October 20th.

Comet *j* (unexpected comet), discovered (photographically) by Dr. FREDERICK L. CHASE, of the Winchester Observatory, Yale University, on November 14th.

In accordance with the regulations, the Comet-Medal has been awarded to the first discoverers of Comets *b*, *c*, *e*, *g*, *h*, *i*, and *j*.

Respectfully submitted,

JAMES E. KEELER (*ex-officio*),

WM. M. PIERSON,

CHAS. BURCKHALTER,

The Committee on the Comet-Medal.

The Treasurer submitted his Annual Report as follows:—

**ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE
FISCAL YEAR ENDING MARCH 25, 1899.**

GENERAL FUND.

Receipts.

Cash Balance, March 26, 1898.....		\$388 78
Received from dues.....	\$1250 71	
" " sale of publications.....	66 70	
" " " stationery.....	65	
" " advertisements.....	72 00	
" " Comet Medal Fund (engraving 14 medals, No. 22-35)....	14 00	
" " Security Savings Bank (interest) ..	1 15	
" " Life Membership Fund (interest).....	84 43	
	<u>\$1489 64</u>	
Less transfer to Life Membership Fund	50 00	1439 64
		<u>\$1828 42</u>

Expenditures.

For publications: printing.....	\$732 10	
" " : illustrations (cuts).....	98 68	
	<u>\$830 78</u>	
Stationery and printing	116 05	
Postages.....	110 21	
Rent.....	180 00	
Salary Secretary-Treasurer	180 00	
Expressages.....	9 39	
Janitor and elevator.....	19 00	
Gas.....	2 80	
Taxes.....	2 71	
Fire insurance premiums	26 25	
Telegrams	4 15	
Collecting dues	11 40	
Lantern at two lectures	20 00	
Engrossing diplomas	6 50	
Engraving nine comet medals (Nos. 27 to 35)	9 00	
Four replicas Bruce Medal and charges.....	10 81	
Ink, boxes, dry plates, and notary fee	4 85	
	<u>\$1543 00</u>	
		<u>\$284 52</u>
Feb. 27, 1899. Advanced to Bruce Medal Fund (second award) ..		59 97
Cash Balance, March 25, 1899.....		<u>\$224 55</u>

LIFE MEMBERSHIP FUND.

Cash Balance, March 26, 1898.....		\$2200 61
Received from General Fund		50 00
" " Interest for 1898..		84 43
		<u>\$2335 04</u>
Less cash advanced to Bruce Medal Fund (see Resolution Vol. XI., page 58)	\$196 66	
" interest transferred to General Fund.....	84 43	
	<u>281 09</u>	
Cash Balance, March 25, 1899.....		<u>\$2053 95</u>

Astronomical Society of the Pacific. 97

BRUCE MEDAL FUND.

Receipts.

Sept. 20, 1897. Cash received from Miss C. W. BRUCE	\$2750 00
Interest for 1897.....	18 30
Cash Balance, March 26, 1898.....	\$2768 30
Interest for 1898	87 44
July 8, 1898. Cash advanced by General Fund \$196 66	
Dec. 16, " " returned to " " 196 66	
" " " " advanced by Life Membership Fund	196 66
Feb. 27, 1899. " advanced by General Fund for Second Award	59 97
	\$3112 37

Expenditures.

Designing and engraving two steel dies (obverse and reverse); engraving two steel hubs (in relief); and the steel ferrule of coining, by ALFRED DUBOIS, Paris	Frs. 2000 @ 5.173 = \$386 62
Price of gold metal } First Award {	Frs. 447 38 = \$86 48
Striking Gold Medal }	50 05 = 9 68
	96 16

The medal is of 22-carat (916/000 fine) gold; the alloy (84/000) is copper; its dimensions are:
diameter : 60 millimeters (the same as the seal of the Society);
thickness at the rim : 3 millimeters;
weight : 141.8 grammes (4.56 oz. troy).

Engraving recipient's name on Gold Medal.	Frs 5 00
Nine bronze replicas @ 2.15	19 35
Four extra bronze replicas (required as a deposit by the French Mint).....	8 60
Four extra bronze replicas. } (Presented to A. DUBOIS)....	21 50
Six bronze cuts. }	
Two bronze cuts.....	4 30
Silvering two cuts.....	2 00
One square morocco case	6 00
Nine round morocco cases @ 1.75.....	15 75
Revenue stamps.	50
Packing and freight to New York.....	16 00

Frs. 99 00 @ 5 173 = 19 14

Duty on nine replicas and charges at New York	6 85
Marine insurance from Paris to San Francisco	60
Express from New York.....	1 25
	\$510 62

Feb. 27, 1899. Remittance to A. DUBOIS, for one Gold Medal (Second Award).....	101 75
	612 37
Cash Balance, March 25, 1899.....	\$2500 00

DONOHUE COMET-MEDAL FUND.

Cash Balance, March 26, 1898.....	\$631 36
Interest for 1898..	24 36
	\$655 72
Less transfer to General Fund (engraving 14 medals, No. 22-35).	14 00
Cash Balance, March 25, 1899	\$641 72

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance, March 26, 1898	\$1562 09
Interest for 1898	60 11
	<u>\$1622 20</u>
Less expended for books, binding, etc.	104 30
Cash Balance, March 25, 1899	<u><u>\$1517 90</u></u>

FUNDS.

Balances on Deposit as follows :

General Fund :	
with Donohoe Kelly Banking Co.	\$215 07
" Security Savings Bank.	9 48
	<u>\$224 55</u>
Life Membership Fund :	
with San Francisco Savings Union	\$853 95
" German Savings and Loan Society.	600 00
" Hibernia Savings and Loan Society	600 00
	<u>\$2053 95</u>
Donohoe Comet-Medal Fund :	
with San Francisco Savings Union	\$213 62
" German Savings and Loan Society	208 13
" Hibernia Savings and Loan Society	219 97
	<u>\$641 72</u>
Alexander Montgomery Library Fund :	
with San Francisco Savings Union	\$483 82
" German Savings and Loan Society	400 00
" Hibernia Savings and Loan Society	634 08
	<u>\$1517 90</u>
Bruce Medal Fund :	
with San Francisco Savings Union.	\$1250 00
" Security Savings Bank.	625 00
" German Savings and Loan Society	625 00
	<u>\$2500 00</u>
	<u><u>\$6938 12</u></u>

SAN FRANCISCO, March 25, 1899.

F. R. ZIEL, *Treasurer*.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN—Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 25, 1899, have made a careful examination, and find same to be correct.

Yours respectfully,

O. VON GELDERN,
F. H. McCONNELL.

March 25, 1899.

President AITKEN then read the annual address.

Mr. BABCOCK presented to the Society, in the name of Dr. E. S. HOLDEN, a large photograph of the Moon, made by Professor DRAPER in September, 1863. The grateful thanks of the Society were returned to Dr. HOLDEN for this most valuable gift.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 25, 1899, at 9:30 P.M.

The new Board of Directors was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected:—

President: Mr. GEORGE C. PARDEE.

First Vice-President: Mr. JAMES E. KEELER.

Second Vice-President: Mr. CHARLES BURCKHALTER.

Third Vice-President: Miss R. O'HALLORAN.

Secretaries: Messrs. C. D. PERRINE, and F. R. ZIEL.

Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. KEELER (*ex-officio*), PIERSON, and BURCKHALTER.

Library Committee: Messrs. TOWNLEY, EDWARDS, and Miss O'HALLORAN. Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. PIERSON, VON GELDERN, and HILL.

The Committee on Publication is composed of: Messrs. AITKEN, TOWNLEY, and VON GELDERN.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. GEORGE C. PARDEE	President
Mr. JAMES E. KEELER	First Vice-President
Mr. CHARLES BURCKHALTER	Second Vice-President
Miss R. O'HALLORAN	Third Vice-President
Mr. C. D. PERRINE	Secretaries
Mr. F. R. ZIEL	
Mr. F. R. ZIEL	Treasurer
Board of Directors—Messrs. BURCKHALTER, CAMPBELL, HILL, KEELER, MOLERA, Miss O'HALLORAN, Messrs. PARDEE, PERRINE, PIERSON, VON GELDERN, ZIEL.	
Finance Committee—Messrs. PIERSON, VON GELDERN, HILL.	
Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.	
Library Committee—Messrs. TOWNLEY, GEO. C. EDWARDS, Miss O'HALLORAN.	
Committee on the Comet-Medal—Messrs. KEELER (<i>ex-officio</i>), PIERSON, BURCKHALTER.	

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

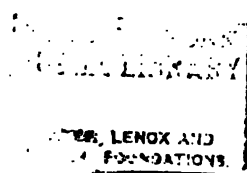
The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

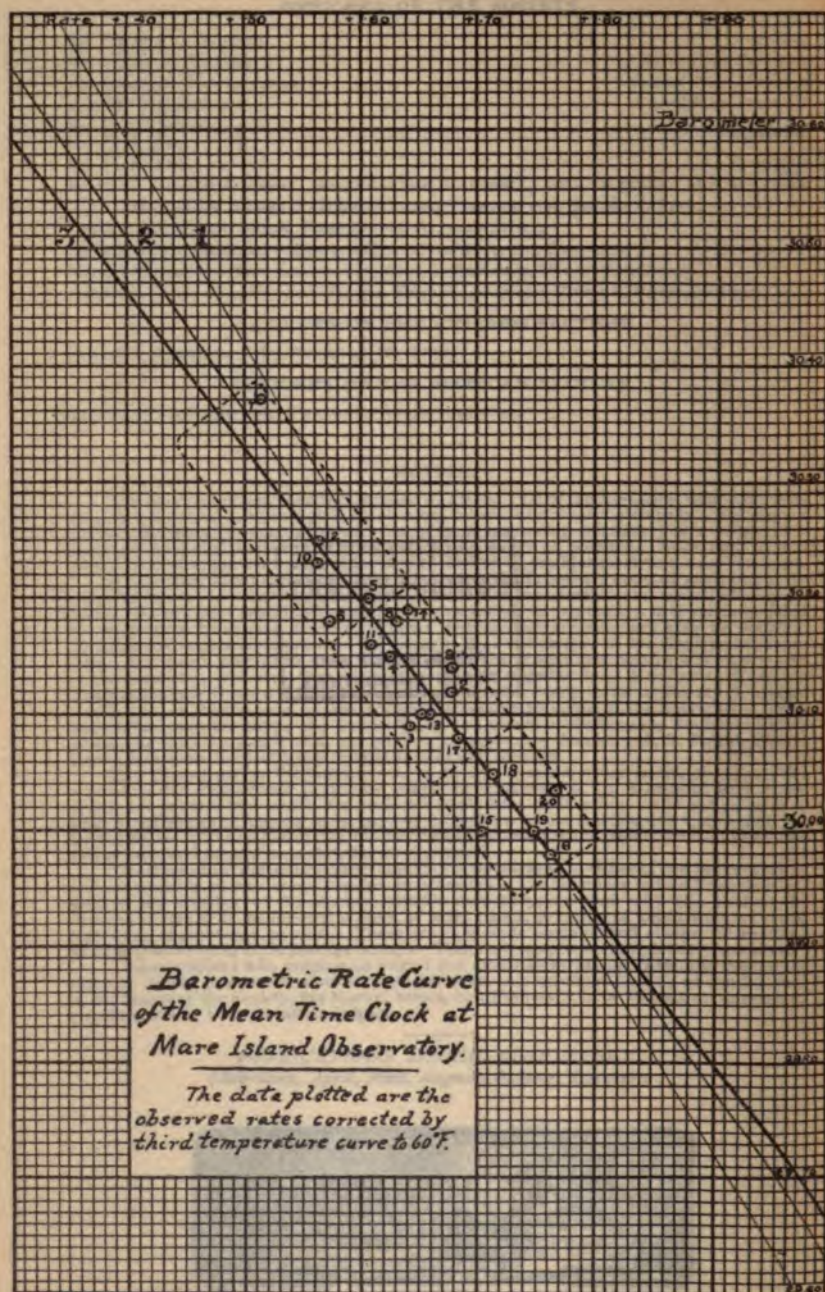
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)







PUBLICATIONS
OF THE

RECEIVED
JUN 1 1899

Astronomical Society of the Pacific.

VOL. XI. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1899. NO. 68.

**CLOCK-RATES AND BAROMETRIC PRESSURE AS
ILLUSTRATED BY THE MEAN-TIME CLOCK
AND THREE CHRONOMETERS AT
MARE ISLAND OBSERVATORY;
WITH A BRIEF ACCOUNT OF THE OBSERVATORY.**

BY ENSIGN EVERETT HAYDEN, U. S. N.

The principal work of the observatory at the Mare Island Navy Yard, California, is the care and rating of chronometers for naval vessels and the sending out of the daily noon-signal, which the wires of the Western Union Telegraph Company flash to every part of the Pacific Coast. The time service of the Naval Observatory at Washington extends as far as Ogden, Utah. West of that point, standard time is supplied by this observatory. These two functions fit in very well together; it is of vital importance to have absolutely correct time, by which to rate chronometers for navigation, both at the observatory (where forty are now on hand and rated daily) and at every seaport along the coast, and the time transmitted for this special purpose is easily made available to the general public also. A shipmaster at San Diego or Seattle, or any other port, can take his chronometer to the telegraph office any week-day in the year, and for the five minutes ending at mean noon of the 120th meridian compare it directly with the clock at Mare Island Observatory, the pulsations of whose pendulum are transmitted instantaneously and audibly through the thousand miles or so of intervening space by the magic of electricity.

The accuracy of the mean-time clock at the Mare Island Observatory—not merely to a second or two, but to a hundredth of a second a day, because even a small daily error

becomes large if it accumulates for a few days — is thus a matter of far-reaching importance.

Some further remarks relative to the observatory, its equipment, work, and history, are appended at the end of this paper, but the primary object is to explain the method that I have adopted in order to find the exact rate of the mean-time clock by means of the observed (corrected) reading of the barometer, irrespective of everything else except a very slight temperature correction, and subject only to disturbances from earthquakes, unfortunately somewhat frequent here, and against which even the best pendulum clock is almost powerless. This clock, however, seems to be less subject to their influence than the sidereal clock, possibly because it faces southwest, while the other faces south, the shocks coming mostly from northwest.

In the great earthquake here on the night of March.30, 1898, for example, which shook down houses, and, of course, stopped all the pendulum clocks, the sidereal clock stopped at $11^h 42^m 17^s$ P.M., 120th meridian time, while the mean-time clock ran thirteen seconds longer.

The clock (No. 624, by E. HOWARD & Co., Boston) has a second's pendulum, with heavy cylindrical bob, mercury temperature compensation, gravity escapement, double case, and is bolted to a substantial masonry pier. Its error and rate are found ordinarily by means of stellar observations with a meridian transit instrument, in connection with the sidereal clock and an electric chronograph.* It has been running here for fifteen years, and was last cleaned and oiled about five years ago.

The special advantage of the barometric rate, the method of obtaining which, and its results, are now to be described, consists in the facility with which it can be obtained, for both short and long intervals, its reliability, its availability, even in cloudy weather, when star-sights cannot be had, and finally its value for use in connection with old records of chronometer rates where daily comparisons with the same clock were recorded.

The plates present graphically the data contained in the accompanying tabular statement, and with a brief explanation will make clear the method followed. It may be said, to begin with, that it is customary in rating chronometers to adopt a ten-day period, from noon to noon, as the interval for which to note

* During the 200 days under consideration there were taken 100 sets of sights, aggregating 1,000 stars

mean rates and temperatures, at the same time keeping a daily comparison-sheet, both as a check and to note maximum variations from the mean rate. My attempt to find a satisfactory barometric rate was based at the start upon this period, and the work developed to such an extent on these lines before final results were reached as to deter me from going back and adopting for this special investigation a period beginning about 9 P.M., when star-sights are exactly available. The mean rates used are therefore subject to some error in working up evening sights to noon of the following day, and are only given to the nearest hundredth of a second, while the corrections are carried out to the third decimal place. It is trusted that general averages have eliminated such errors; otherwise, they must still be present in the final results. The rate-curves are assumed to be straight lines within the limits of the diagrams.

The temperature is the mean of observations at noon daily of a Six's maximum and minimum thermometer kept in the chronometer-case in the middle of the room. This is found by trial to differ very little from the mean of hourly readings of a standard thermometer in the inner clock-case, read through glazed windows in the double doors. The barometer record is the two-hourly mean from copies of barograph sheets kindly supplied by the office of the United States Weather Bureau in San Francisco, corrected and reduced by the addition of .16 inch, and confirmed by curves drawn from my own observations of a standard mercurial barometer at the observatory.

The relative humidity is obtained from daily noon readings of an ordinary wet and dry bulb thermometer in the clock-room. This record is not regarded as of any special value, and need not be considered further than to say that it is shown graphically on the plate in connection with the curve showing final errors of the barometric rate, with which curve it is so inconsistent as not to justify further correction. The best inference that can be drawn from it seems to be that an increase of one per cent. above normal (84 per cent.) makes the clock run about .01^s per day more slowly.

The tabular statement gives all the observed data; the data by which the successive approximate curves are drawn; the final errors of the barometric rate-curve at normal temperature (60° Fahr.) for each of the twenty periods; and finally, the accumulated error up to the end of each successive period, amounting in all to two hundred days:—

DATA AND RESULTS OF THE BAROMETRIC RATE OF

Period.	Ending at Noon.	No. of Days.	MEAN OBSERVED DATA. (Par. Corrected and Reduced.)				Rate corrected to 60° F., by Temp. Curve No. 1.	BAROMETRIC RATE-CURVE NO. 1.		
			Temp.	Bar.	Rate. (gaining)	Rel. Humid.		Data.	Rate.	Error.†
			°F.	In.	Sec.	Per cent.				
1	Nov. 1	10	65.78	30.10	+.66	80.0	.620	Means of Periods	.683	— .063
2	13	12	61.29	30.12	.68	80.0	.670	16, 17, 19 20, 21:	.672	— .002
3	21	8	57.94	30.09	.64	82.9	.654	Bar. 30.013	.689	— .035
4	Dec. 1	10	54.85	30.15	.62	84.6	.650	Rate, .737	.653	— .003
5	11	10	54.28	30.20	.60	78.1	.635		.624	+ .011
6	21	10	47.78	30.18	.56	86.5	.635	Periods 2, 3, 4, 5, 9, 10, 12, 14, 15, 18:	.635	0
7	31	10	46.98	30.37	.50	84.8	.580	Bar. 30.126	.526	+ .054
8	Jan. 10	10	48.18	30.18	.62	89.2	.692	Rate, .662	.635	+ .057
9	20	10	52.55	30.14	.67	90.6	.716		.660	+ .056
10	30	10	57.68	30.23	.56	81.0	.574		.606	— .032
11	Feb. 9	10	50.93	30.16	.60	83.8	.657	Periods 6, 7, 8, 11, 13:	.648	+ .009
12	19	10	56.08	30.25	.56	85.8	.584	Bar. 30.246	.595	— .011
13	Mar. 1	10	61.20	30.10	.66	79.0	.652	Rate, .602	.683	— .031
14	11	10	59.25	30.19	.64	82.0	.643		.630	+ .013
15	21	10	55.13	30.00	.70	87.3	.730	Points of Curve: 30.60 .393 and 29.60 .972	.740	— .010
16	31	10	58.43	29.98	.76	86.9	.769		.751	+ .018
17	Apr. 10	10	64.00	30.08	.69	86.3	.663		.695	— .032
18	20	10	64.65	30.05	.72	83.4	.688		.711	— .023
19	30	10	60.70	30.00	.75	84.0	.745	Angle. 59°55' 45''	.740	+ .005
20	May 10	10	62.15	30.035	.77	83.7	.755		.720	+ .035
Mean for 200 days			56.53	30.13	+.65	84.0				

* Relative Humidity for Period No. 1 assumed to be same as for No. 2. Data missing.

† In error of Barometric Rate, + signifies that it would make noon-signal too early; —, too late.

MEAN-TIME CLOCK AT MARE ISLAND OBSERVATORY.

BAROMETRIC RATE-CURVE NO. 2.			Rate corrected to 60° F. by Temp. Curve No. 3.	BAROMETRIC RATE-CURVE NO. 3			TOTAL ERROR OF BAROMETRIC RATE FROM CURVE NO. 3.	
Data.	Rate.	Error.		Data.	Rate.	Error.	For Period.	To Date.
Means of Periods	.677	— .039	.652	Means of Periods	.672	— .020	— .20	— .20
16, 17, 19, 20, 21:	.664	+ .012	.678	16, 17, 19, 20, 21:	.656	+ .022	+ .264	+ .064
Bar. 30.013	.683	— .037	.642	Bar. 30.013	.680	— .038	— .304	— .24
Rate, .739	.649	— .012	.625	Rate, .739	.634	— .009	— .09	— .33
	.607	+ .012	.605		.597	+ .008	+ .08	— .25
Periods 2, 3, 4, 5, 9, 10, 12, 14, 15, 18:	.621	— .021	.572	Periods 2, 3, 4, 5, 9, 10, 12, 14, 15, 18:	.610	— .038	— .38	— .63
Bar. 30.126	.621	+ .037	.631	Bar. 30.126	.610	+ .021	+ .21	+ .01
Rate, .655	.649	+ .045	.678	Rate, .650	.641	+ .037	+ .37	+ .38
	.587	— .020	.562		.574	— .012	— .12	+ .26
Periods 7, 8, 11, 13:	.635	— .005	.609	Periods 6, 7, 8, 11, 13:	.626	— .017	— .17	+ .09
Bar. 30.246	.573	0	.563	Bar. 30.246	.558	+ .005	+ .05	+ .14
Rate, .580	.677	— .021	.658	Rate, .563	.672	— .014	— .14	0
	.614	+ .027	.640		.604	+ .036	+ .36	+ .36
	.745	— .029	.704		.747	— .043	— .43	— .07
Points of Curve:	.758	+ .007	.761	Points of Curve:	.761	0	0	— .07
30.60 .335 and 29.60 1.0 17	.690	— .015	.684	30.60 .294 and 29.60 1.049	.687	— .003	— .03	— .10
Angle, 52° 41' 25"	.710	— .007	.714	Angle, 52° 56' 05"	.710	+ .004	+ .04	— .06
	.745	+ .003	.749		.747	+ .002	+ .02	— .04
	.720	+ .042	.767		.721	+ .046	+ .46	+ .42

* Several light earthquake shocks occurred during the last period, and occasionally throughout the entire interval.

The first approximate temperature rate-curve is derived directly from the diagram where clock-rate and barometer for each period are plotted on ordinates of the temperature-scale; from these data the positions of points at high, medium, and low temperatures, at normal pressure of 30.00 inches, are estimated, and the temperature rate-curve drawn by means of these three points. Using this curve to reduce the observed rates to 60° Fahr., the first barometer rate-curve is drawn. From this the barometric rate is measured for the observed mean pressure of each period, and by comparison with the observed rates (as already corrected for temperature), the column and corresponding curve of errors are made out. The inclination of this last curve, as plotted on the temperature-sheet, furnishes an evident correction to the first temperature rate-curve. This correction, properly applied, gives the second temperature rate-curve. This process is then repeated once more, giving the third (and last) temperature and barometer rate-curves. The errors of the last-named curve for each period are given in the next to last column of the table, and shown graphically on the temperature-sheet, where, as stated above, the relative humidity curve also is shown. The last column gives the total accumulated error up to the end of each successive period, and is not shown graphically.

The last two columns may be assumed to represent the results that would have followed the use, without any star-sights at all, of the thermometric and barometric rate-curves ever since last October, under the actual conditions that prevailed, including a number of light and two or three rather sharp shocks of earthquake. In the last period, ending May 10th, I myself noticed and timed four shocks, of which one was sharp enough to be startling. It will be noticed that the two maximum errors for single periods are .46" (in the last period) and .43" (in the fifteenth). This is certainly not bad; an error of less than half a second in ten days, without using any star-sights, especially where we have an occasional earthquake to explain even this! But it will be seen, further, that twelve of the twenty periods have an error of only .21" or less, and of these twelve there are seven with practically no error at all. Those specially interested can compare the periods where the error is larger or smaller, respectively, with the graphic record of mean daily barometer. It will be found that the larger discrepancies in rate correspond, generally, with erratic behavior of the barometer.

Examining now the last column, or the accumulated error to end of each successive period, the maximum, .63", at end of the sixth period, is large in comparison with the rest, as the plus and minus errors cancel each other in a way that made me both surprised and pleased, leaving the total accumulated error one tenth of a second, or less, in ten of the twenty periods. In a word, had these rate-curves been used, without a single star-sight, since last October, the noon-signal would never have been more than six tenths of a second wrong, seldom more than one tenth, and at the end of April correct within a few hundredths of a second.

Having now examined the possibilities of error of the barometer-rate used alone, without the star-rate, let us next examine the possibilities of error of the star-rate without the barometer-rate. Take, for example, four days of abnormally high pressure, from noon, December 23d, to noon, December 26th, and of abnormally low pressure, January 9th to 12th. The mean temperature in the former period was 46°.9, and in the latter, 48°.7, giving a correction of —.01 to apply to the barometer-rate at 60°, in each case. Using the star-rate as actually observed at the beginning of each period, we have:—

Date	Dec. 23	24	25	26	Jan. 9	10	11	12
Barometer	30.32	30.31	30.59	30.45	30.21	29.95	29.57	29.84
Star-rate	.53	.53	.53	.53	.63	.63	.63	.63
Bar.-rate.	.50	.35	.29	.40	.58	.77	1.06	.85
Error of } Daily .	— .03	— .18	— .24	— .13	— .05	+ .14	+ .43	+ .22
star-rate } Total .	— .03	— .21	— .45	— .58	— .05	+ .09	+ .52	+ .74

In other words, the star-rate, used alone, is liable to a greater error in four days than the barometer-rate, used alone, is in two hundred days. In the examples given here, I have assumed the barometer-rate to be the correct rate, which it practically is, so far as these examples are concerned. The chances of four days of cloudy weather and no star-sights, more especially when the barometer is low, are of course very great.

I have applied the same method of investigation to the sidereal clock, and with very nearly as good results, and use both clocks in verifying the time before sending out the noon-signal. The two almost invariably agree within a few hundredths of a second, when their different rates are worked up according to this method. I always use the barometer-rate also

in working up an evening star-sight to noon of the following day, and have used it to obtain chronometer rates from old records, where the rate only was wanted, the total error on Greenwich mean time not being required.

One cannot but form the impression, in studying these results, that a first-rate pendulum clock, well worn down to its bearings by long years of steady running, carefully mounted and protected from dust and from sudden change of temperature, and free from earth tremors of any kind, must keep even better time than we give it credit for, if only we make proper allowances for its regular and entirely reasonable variations under different conditions of temperature and pressure. An attempt was made in the present case to account for a part, at least, of the final errors by the effect of the other mean-time clock in the same room, but as the latter is always corrected daily at noon, the task proved impracticable. Similarly, an attempt to associate them with lunar or tidal influence failed, although it may be worth mentioning that the error-curve of the barometer-rate of the sidereal clock shows a very marked resemblance to a curve of the mean stage of the tide for each period at the entrance to San Francisco Bay. Finally, to try to allow for the lagging of the pendulum, barometric means were calculated for periods beginning a day earlier, but their use gave less favorable results.

Nevertheless, such attempts might succeed, under more favorable circumstances, and the final errors be reduced almost to the vanishing-point. If so, it could justly be claimed that the accuracy of motion of such a clock is actually comparable to that of the earth upon its axis, and that as a perfectly running machine it is, perhaps, the very best production of human brains and hands.

CHRONOMETER RATES AND BAROMETRIC PRESSURE.

After obtaining such satisfactory results with the barometric rate of the mean-time clock, I began an exhaustive investigation of the effect of changes of atmospheric pressure upon the rates of chronometers. In this work the data for the usual ten-day periods, already available, were supplemented by data obtained by means of the established thermometric and barometric rates of the clock and the recorded daily comparisons of the chronometers. Selecting five-day periods of high and low barometer, I was thus enabled to obtain the rates of the chronometers for those periods with

great confidence, irrespective of star-sights. The results of the combined ten-day and five-day data, when consistent, can hardly fail to command confidence, and even when inconsistent they give useful, though negative, information.

Although this work is not yet completed, it seems evident that the best chronometers show a remarkably regular change of rate for differences of pressure, running about $.10^s$ faster for a decrease of .10 inch of mean barometer. This amount is large enough to demand consideration in calculating mean data and resulting rate-curves, and it seems to be clearly established that the rate-curves of such chronometers should be drawn for a mean pressure of 30 00 inches, with similar curves to the right and left for each tenth lower and higher pressure, respectively, for, say, five tenths of an inch, for the practical use of navigators.

Unfortunately, there are no means available here for obtaining, artificially, mean high temperatures by which to observe rates, and thus fix more accurately the upper branch of the parabola, now determined from observations of one branch only, the vertices of the curves, as chronometers are usually compensated, lying about the maximum mean summer temperature. Thus slight errors, or variations of rate, may introduce decided errors in the curves as plotted from equations deduced from the observed data. Another necessity is a self-recording thermometer and barometer, for better temperature and pressure data, and a seismograph, in order to avoid errors due to earth-tremors not otherwise noticed.

It is not claimed that all chronometers show equally good results as regards effect of changes of pressure, but only the best of them. In fact, I find that when a chronometer shows decided evidences of polarity, the relation between rate and pressure seems sometimes to be actually reversed.

The plate entitled "Chronometer Rate-Curves" gives the lower branches of the temperature-rate parabolas calculated for the three standard Negus chronometers issued to the U. S. S. *Nero*, Captain CHARLES BELKNAP, U. S. N., commanding, now engaged in surveying for a cable route to Manila. Her navigator, Lieut. JOHN HOOD, has agreed to take special care with the thermometer and barometer record (not always very reliable, even aboard a man-of-war), and his report will be of great interest, as indicating the value of the method in actual practice. The absence of data at high temperatures, however, and errors that are

liable therefrom, must still be remembered and allowed for. The first of the three curves is plotted from data observed with XII South, the other two from data for nearly equal intervals of time with XII North and XII South, care being taken to give equal weight, in obtaining mean data for the curves, to observations on the two headings. The data used to obtain mean values for a single point of the three from which the equation of a curve is deduced are inclosed by a dotted line. Such mean values are corrected to a normal pressure of 30.00 inches before being used in the equations, and the difference between the curves thus worked out and those that would result from the same data uncorrected for pressure is evident at a glance. For a long voyage, like that of the *Nero*, where accuracy of navigation is more than usually desirable, the value of this method can hardly be denied.

The data for the regular ten-day periods, as regards temperature, barometer, and humidity, are the same as for the mean-time clock. Additional data are as follows:—

Chronometer-Rates for 10-day Periods, October–December :

Period No.	1	2	3	4	5	6	7
Rates { 1639 Negus, . . .		-.75	-.83	-.97	-1.10	-1.69	-2.13
1209	+1.08	+.96	+.95	+.73	+.64	+.33	+.20

Chronometer-Rates for 10-day Periods, January–April :

Period No.	8	9	10	11	12	13	14	15	16	17
Rates { 1141 . . .		-1.06	-.81	-1.32	-.92	-.58	-.75	-.95	-.60	-.41
1639	-2.21	-1.90	-1.37	-1.56	-1.37	-.91	-.93	-1.14	-1.07	-.85
1209	-.21	+.13	+.52	-.07	+.34	+.70	+.57	+.30	+.49	+.86

For Period No. 17½, 5 days ending noon, April 15th: temp. 65.20, bar. 30.02; rates, 1141 Negus, — .34; 1639 Negus, — .80; 1209 Negus, + 1.04.

Special 5-day Periods of High and Low Barometer (Data obtained from rate-curves of mean-time clock and daily comparisons of chronometers. Positions not plotted on the diagrams):

5 days end'g noon	Jan. 8	Jan. 14	Jan. 24	Feb. 3	Feb. 10	Feb. 25	Mar. 20	Apr. 6
Bar.	30.35	29.90	30.35	29.95	30.39	30.03	29.94	30.12
Temp.	48.10	48.80	54.85	56.50	48.40	62.55	54.25	62.45
Rates { 1141 Negus . . .			-1.22	-.60	-1.78	-.43	-.93	-.50
1639	-2.37	-2.07	-1.70	-.98	-1.98	-.81	-1.19	-.88
1209	-.27	-.01	+.18	+.58	-.46	+.83	+.35	+.64

5° FAHR

TENT

CHRONOMETER RATE-CURVE FOR TEMPERATURE BAROMETER, AND HEIGHT

—○— XII NORTH
- - -○- - - XII SOUTH

NUMBERS OF PERIODS
SAME AS FOR THE
MEAN TIME CLOCK:
THOSE USED TO PLOT
CURVES ENCLOSED
BY DOTTED LINE.

55°

50°

30.30 30.40 30.50 30.60 30.70

114.1 NE

30.30 30.40 30.50 30.60 29.90 29.80 29.70

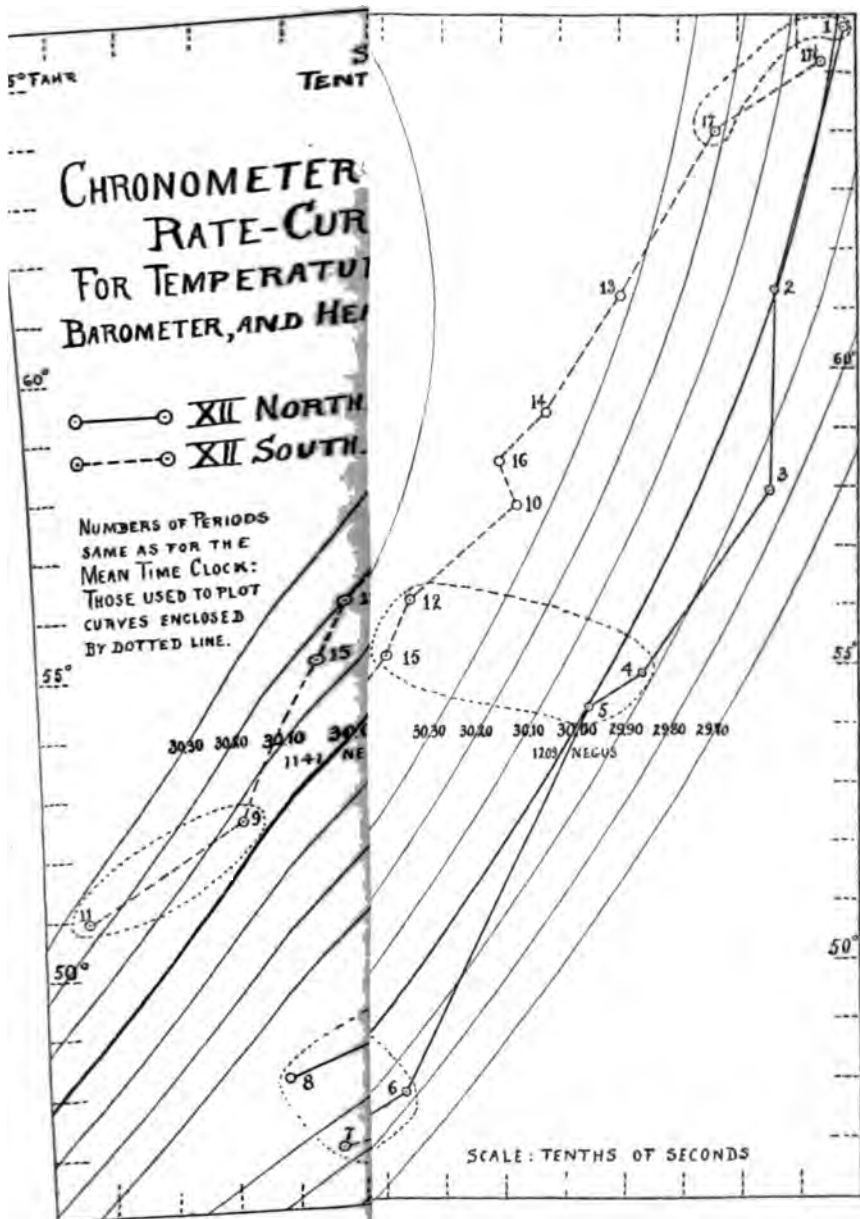
120.9 NEGUS

60°

55°

50°

SCALE: TENTHS OF SECONDS



All the data have now been given, and it remains only to explain briefly how the barometer correction has been obtained.

Taking the first chronometer (1141 Negus) as an example, we have :

Period No. 14:	Bar., 30.19	Temp., 59.25	Rate, — .75
10:	30.23	57.68	— .81
Mean:	30.21	58.47	— .78
Period No. 16:	29.98	58.43	— .60
Difference:	.23	.04	.18

The temperature difference being here so small, we can assume that the entire difference of rate is due to difference of pressure, which means that a difference of .10 inch barometer causes .08° difference of rate. When the difference of temperature is appreciable, it is easily allowed for by estimating the direction of the tangent to the curve and applying a suitable correction.

. Using now the data of the 5-day periods, we have:

Period ending noon, Feb. 25:	Bar., 30.03	Temp., 62.55	Rate, —.43
April 6:	30.12	62.45	— .50
Difference	.09	.10	.07

An approximate tangent to the curve gives, for temperature of 5°, a rate of .20°, and for 0°.10 a correction of .004. Applying this correction, there remains a difference of rate of .066, caused by the difference of pressure of .09 inch. This gives, for .10 barometer, a difference of rate of .073°, a close approximation to the former result of .08°.

Again, using other 5-day periods,—

Period ending noon, March 20:	Bar. 29.94	Temp. 54.25	Rate — .93
Period ending noon, Feb. 3:	29.95	56.50	— .60
Mean:	29.94	55.38	— .77
Period ending noon, Jan. 24:	30.35	54.85	— 1.22
Difference:	.41	.53	.45

Approximate tangent gives: 5° = .30°; correction for 0°.53 = .032°. Correcting for temperature, as before, we get: .10 bar. = .105°. The mean of .073 and .105 is .089, showing that the rate of .08 first obtained was reliable. This correction is now used to reduce the means of points grouped together on the diagram, in order to obtain data for a normal pressure of 30.00 inches, and the three corrected means on each curve used to work out its equation.

This same process was followed in the two other cases illustrated, although, there being data for XII North and XII South, an equal number of points on each heading were grouped together from which to obtain data for the equation of the curve.

The results are in many cases so consistent as to convince any one that in those cases, at least, this method of correcting temperature rate-curves to a normal pressure of 30.00 inches, and of using the barometric rate in actual practice, is well worth a trial. Generally speaking, abnormally high temperatures accompany abnormally low pressures, and *vice-versa*, so that the use of data for temperature and rate, uncorrected for pressure, has an evident tendency to distort the resulting curve. The value and limitations of the temperature rate-curve are recognized, and this barometric correction should be recognized likewise.

THE MARE ISLAND OBSERVATORY, CALIFORNIA.

GEOGRAPHIC POSITION:

Lat., $38^{\circ} 05' 55''.8$ N.

Long., $122^{\circ} 16' 19''.3$ W.

Location, on the crest of a hill, about sixty feet above mean low water, and near the northern extremity of the island.

The observatory consists of two brick buildings, one of them two stories high, with a 5-inch ALVAN CLARK & SONS' equatorial (No. 861), mounted on a substantial masonry pier built up through the center of the building; the other brick building is the clock, chronometer, and chronograph-room, and the two are joined by a light wooden structure forming the transit-room. The transit-room contains three piers, two of them central, with sliding shutters overhead. Of these, only one set is now in use.* Leading out of the transit-room is a small hall-room, used as a battery-room. The transit instrument is of 2.5-inch aperture, No. 1508, STACKPOLE BROS., New York.

The three clocks are very similar to each other, and all are by E. HOWARD & CO., Boston. The mean-time and sidereal clocks are mounted on separate masonry piers, and have double cases. The transmitter-clock is hung to the south wall, and has but a single case. All three have mercury-compensated pendulums and gravity escapements. The first is No. 624, the second 627, and the third 622.

The observatory was established in 1884, through the efforts, principally, of Lieutenant (now Lieutenant-Commander) U. R. HARRIS, U. S. N., under the direction of Commodore JOHN H.

*One of the spare piers is now occupied by a Ewing seismograph, kindly loaned by the Director of the Lick Observatory.

RUSSELL, Commandant of the Navy Yard, and Commodore (now Rear Admiral) JOHN G. WALKER, Chief of Bureau of Navigation, for the purpose of supplying standard time to this coast, as the Naval Observatory, at Washington, does to the East and South coasts, and for the care and rating of chronometers (of which, as already stated, there are forty now on hand, running and compared daily). The principal object in view was then, and is now, the storage and supplying to naval vessels of accurately rated chronometers and the furnishing to shipmasters in any of our ports facilities for comparing and rating their own chronometers, either by means of time-balls, dropped electrically at noon, or by visits to the local telegraph offices, where the signals are received. Incidentally, the time service is, of course, of great general benefit and utility, but it should be remembered that the great modern improvement in accuracy of clocks, watches, and time generally is primarily due to and a result of the needs of navigators. The details regarding methods of rating chronometers are of great interest, but cannot be considered here. It may be of interest to mention, however, that chronometers cost from \$200 to \$500 apiece; that some still in use are as much as fifty years old; that several of these were captured during our Civil War, and that one of the best, if not the very best, firm of chronometer-makers in the world is located in New York.

Another service that has been performed at the observatory from time to time is compass and magnetic work, and the care and issue of sextants, portable transits, and meteorological instruments. The magnetic and compass work, however, is now carried on entirely by the compass office in Washington.

Other naval officers who have been in charge of or assistants at the observatory for a year or more at a time, to whom also credit is due, are Lieutenant-Commanders J. B. MILTON and W. E. SEWELL, and Lieutenants C. F. POND and D. P. MENE-FEE. To Mr. POND, especially, who succeeded Mr. HARRIS, is due the completion of the transit-room in its present form. As a rule, there has been no assistant, and there is none now, all the work being performed by the officer in charge. Considering this fact, and the importance of the interests confided to its charge, its record is certainly creditable, but there is nevertheless urgent need for more of an element of permanency and continuity in its management, work, records, and library. An entire change every two or three years, while essential and desira-

ble in ordinary naval routine work, is not very well adapted to work of this character.

Much credit for the practical efficiency of the time service is due to the Hydrographic Office and its branch offices for co-operation in connection with time-balls and other methods of distributing the time amongst navigators, and to the Western Union Telegraph Company, which also itself utilizes the time by correcting electrically many hundreds of clocks daily, and which has been of great assistance in connection with telegraphic longitude determinations and occasional time-signals to surveying vessels far south along the coast of Lower California.

If the investigation explained in the accompanying paper adds to the efficiency of this service, and to that of other services engaged in similar work, the writer will feel well repaid for the study and effort devoted to it at intervals between pressing official duties during the past six months.

THE RISE AND PROGRESS OF ASTRONOMY IN CENTRAL EUROPE.

BY SIDNEY D. TOWNLEY.

During a stay abroad in 1895 and 1896, the writer obtained photographs of many of the observatories of Germany. It was thought that a reproduction of some of these views, together with descriptions of the buildings and instruments and short historical accounts of these observatories, would be of interest to the students of astronomy. In preparing the material for publication the scope of the work, as often happens, has been enlarged gradually, until it has reached that indicated in the above title. The title should perhaps have been somewhat restricted — for it is my intention to treat mainly of the practical or observational side of astronomy, and to touch upon considerations of a theoretical nature only in so far as is necessary to bring out the development of the practical branch of the science.

Six names, COPERNICUS, TYCHO BRAHE, KEPLER, GALILEO, GAUSS, and BESSEL, stand out pre-eminently prominent. These are almost household words to the student of astronomy. Their lives and works are familiar to nearly every one. Some of them

have been written and rewritten in the greatest of detail. It is not my purpose to go into the details, but a proper development of the subject in hand demands at least an outline of the works of these men.

The fall of Constantinople (1453) marks the beginning of modern astronomy. The sages who had gathered in the Grecian empire were scattered over Western Europe. To be sure, the Ptolemaic system was introduced into Spain some centuries before this. The Alphonsine tables were computed in the thirteenth century; but this was only a faint and solitary star in the firmament of the dark ages, and it was entirely lost in the dawn that slowly spread over Central and Western Europe in the fifteenth century. The Ptolemaic system of the universe had been accepted and taught for centuries, and it was not until the epoch-making work of COPERNICUS was put forth that the foundations of this mighty edifice of epicycles began to totter.

Although the work of COPERNICUS was the first great one in the progress of which we are dealing, still a beginning had already been made when COPERNICUS appeared, and it is perhaps well to note first these early attempts. One event leads to another, and it is seldom that even the work of a great genius stands alone. Previous events have created an atmosphere of unrest, indicated the necessity of change, perhaps even pointed out the way or laid a foundation for his work. The great man seems to come when the conditions are ripe for his coming.

The first astronomer of note of whom history tells us was GEORGE PURBACH, an Austrian (1423-1461). In a work, *Theorica Novæ Planetarum*, he attempted to revive the old method of material spheres. Learned men were then beginning to pay some attention to physical subjects, and PURBACH doubtless had difficulty in perceiving why, without any known cause, celestial bodies should describe in space circumferences of imaginary circles whose centers moved upon the circumferences of other circles equally imaginary. Vastly more important, however, was PURBACH's other contribution to astronomy—the introduction into Europe of the methods of trigonometry, invented several centuries before by the Arabians. PTOLEMY's methods were all geometric; and when we stop to think of how dependent practical astronomy is upon the methods of trigonometry we can scarcely overestimate the importance of PURBACH's effort in this direction. This was the beginning of those transformations

which finally led in the practical astronomy to the simple, elegant, and exact formulæ of the great BESSEL.

Among the pupils of PURBACH the most noted was JOHANN MUELLER (1436-1476), born in Königsberg, and generally known by the name of REGIOMONTANUS. He soon became a co-worker with PURBACH, and the two not only studied diligently the works of PTOLEMY, which had been the extent of astronomical study for centuries, but *began taking observations* in Vienna with some crude instruments, perhaps not even so accurate as those possessed by HIPPARCHUS. Crude as these instruments were, they were yet sufficient to show that the positions of the planets given by the Alphonsine tables differed widely from the true positions. After PURBACH's death REGIOMONTANUS traveled in Italy, and while in Venice wrote a treatise on trigonometry and constructed a table of tangents. He did much to develop and extend the application of this useful branch of mathematics. In 1471, he returned to Germany, and settled in Nuremburg, at that time the chief center of German industry and literary life. Here, through the co-operation of a wealthy citizen, BERNARD WALTHER (1430-1504), the first European observatory was built, and observations begun about 1472. A comet was observed by them in that year. They originated several new methods of observing, and greatly improved the method of recording the time of an observation. The method of the ancients was very rough—simply morning, evening, or midnight. The Greeks used a clepsydra or a sun-dial, but it was not until the time of REGIOMONTANUS that a more accurate method was introduced. His method was to determine the time of observation by an altitude of the Sun or a star simultaneously taken, a method susceptible of great precision. WALTHER was the first to make use of clocks to measure short intervals of time. The clock consisted of wheel works to which motion was given by a weight, but it was not until the time of GALILEO that a pendulum was added to control the running of the clock. WALTHER was also the first to employ a more accurate method of observing the positions of the planets. In ancient times the longitude and latitude of a planet were observed with an astrolabe, the longitude being obtained when the Sun and Moon were visible at the same time. First, the difference in longitude between the Sun and Moon was measured, then the difference in longitude between the Moon and planet. The longitude of the

Sun was taken from the tables, then, by means of these two differences, the longitude of the planet was obtained. The latitude was measured directly with the astrolabe. Now, WALTHER, instead, measured the angular distance of the planet from two or more known stars, and then, by the methods of spherical trigonometry computed the latitude and longitude of the planet, a method in some respects similar to that now used to determine the position of a planet or comet with an equatorial telescope.

That, however, which added most to the fame of REGIOMONTANUS was the publication of his celebrated ephemerides, the first of those important adjuncts of practical astronomy. The ephemerides were soon made known to navigators, and it was by the aid of these that COLUMBUS first crossed the Atlantic Ocean. REGIOMONTANUS met an early death, but during the twenty-eight years that WALTHER survived him many observations were made at Nuremburg. These were published in 1544.

But one other name of note remains to be mentioned before coming to COPERNICUS. PETER APIANUS, who taught in the university at Ingolstadt, published in 1540 a large work, *Astronomium Casareum*, an attempt to further prolong the life of the Ptolemaic system. The book was highly received at the time. But APIANUS is perhaps more deserving of a place in history from the fact that he was the first to discover that the tail of a comet is always turned away from the Sun.

Thus, though the Ptolemaic system was still tenaciously clung to, yet considerable had been accomplished before COPERNICUS appeared on the scene. Trigonometry was introduced and developed, tables of sines and tangents constructed, ephemerides published, observations made, clocks used, and, above all, a spirit of investigation had arisen. The Ptolemaic system had become exceedingly cumbersome, and observations showed, after a lapse of fourteen hundred years, though epicycle upon epicycle had been added, that it represented the true motions of the planets very imperfectly. The time was ripe for a COPERNICUS. He came.

Born at Thorn, a town of the Hansa League, then under the sovereignty of Poland, NICOLAUS COPERNICUS (1473-1543) studied at Krakau and Bologna, taught and took orders in Rome, later returned to his native country, settled in Frauenburg, Prussia, and there spent most of his life. At Krakau he became a doctor of medicine, and did not study mathematics

and astronomy seriously until he went to Bologna. At Rome, COPERNICUS was installed as professor of mathematics. Here he began to make astronomical observations. The fame of these and the clearness of his lectures soon gained for him a place among the most learned of astronomers. His observations were continued later at Frauenburg. These observations consisted in obtaining the longitudes and latitudes of the planets, the obliquity of the ecliptic, and the period of the Sun's return to the equinoxes. COPERNICUS, however, never entered seriously into the business of observing, and the results in this line were insignificant compared with those of TYCHO, brought forth a few years later.

At Frauenburg COPERNICUS led an uneventful life as a canon of the Church. Of his daily labors we know but little; still much of his time must have been given to matters astronomical, else he could never have given to the world that great work, *De Revolutionibus Orbium Cælestium*, published in 1543, only a short time before his death. Of this work it is perhaps necessary to say but little. Its great principles are familiar to all students of astronomy. It is perhaps well to point out, however, that the system promulgated by COPERNICUS was in some ways essentially different from that which now bears his name. COPERNICUS brought forth only a portion of the truth. He substituted diurnal motion of the Earth for the diurnal motion of the heavens, and a heliocentric motion of the planets and the Earth for a geocentric motion of the planets and the Sun. These were two great principles, and in that much the present system is rightly called Copernican. This, however, was only a beginning, and it was not until TYCHO, KEPLER, GALILEO, and NEWTON had lived and worked that the true nature of planetary movements became known. COPERNICUS still held to the idea of circular motion; so, in order to explain the irregular apparent motions of the planets and the variation in the apparent diameter of the Sun and Moon, he was obliged to retain some of the epicycles of the Ptolemaic system.

Even though COPERNICUS discovered only a portion of the truth, still his researches marked a great advance, and when we think of the condition of learning, and especially of science at the time he lived, we cannot have other than profound admiration for the man possessed of an intellect to work out these theories, and the boldness to present them to the world. The world had only

begun to awaken from the long sleep. Aristotelian philosophy was still firmly intrenched in all citadels of learning, the Ptolemaic system of the universe had reigned undisputed for fourteen hundred years, the Scriptures were everywhere interpreted literally; the Sun, Moon, and stars were made for the glory of the Earth, and to dispute this and consider the Earth as but one of many, as COPERNICUS did, was little short of heresy. Perhaps it is fortunate that COPERNICUS did not long survive the publication of his work. COPERNICUS had taught his system quietly for many years, but it was not until long after his death, that it came under the censure of the Church. Perhaps the facts that COPERNICUS himself was a churchman, that the cost of his book was defrayed by a cardinal of the Church, and that the book itself was dedicated to the Pope, acted to disarm suspicion. COPERNICUS was certainly shrewd, perhaps unwittingly so.

Many years elapsed before the theory of COPERNICUS was generally accepted and the Ptolemaic system finally abandoned. This is not to be wondered at, when we consider that there was then no proof that the Earth moved. That came much later, when the flattening of the Earth was found, aberration discovered, and the memorable experiments of GALILEO and FOUCAULT performed. In fact, about the only thing that recommended the Copernican theory was its simplicity. The Ptolemaic theory had much in its favor. It had been accepted as true for hundreds of years; our sense of sight tells us that the heavens move above us and not the Earth beneath us; it agreed with the teachings of the Church. And when we consider the great weight then given to things ancient and the great power of the Church, the wonder perhaps is that the Copernican theory found as many followers as it did.

The theory of the Earth's motion was not original with COPERNICUS, for it was advanced many hundred years before by a Greek philosopher. Why was the theory accepted in the sixteenth century and rejected in ancient Greece? No doubt, one great factor was the earnestness and power with which COPERNICUS taught this theory to his pupils. Yet, on the other hand, there were conditions which favored COPERNICUS; the newly invented art of printing preserved and propagated his ideas; he lived at a time when the spirit of change, revival, and reformation was abroad; he lived at a time when the Ptolemaic system had been tried sufficiently long to be found cumbersome and unsatisfactory.

Although the work of COPERNICUS led to great results, yet his methods were not scientific. Astronomy, indeed, had hardly yet become a science. It might, perhaps, have been rightly called mathematical speculation. The deductive method of mathematics was used. Axioms were assumed, and the consequences deduced by processes of reasoning. It had not yet been perceived that the true method of scientific research is an inductive one. Observations must first be made and facts ascertained. The theory must be in accord with the facts. If this is not the case, then the theory is certainly false. If the theory does satisfy the facts, then it may be true. We shall see in the next paper how the great Danish astronomer was the first to perceive and carry out true and accurate methods of scientific research.

In criticising and pointing out defects in the work of COPERNICUS, I do not wish the reader to think that I underestimate his work. The defects belonged more to the age than to the man. His work was profound, it was epoch-making; still he was not by any means a genius; things did not come to him by inspiration. He was a quiet, deep, incessant thinker, earnest in his belief and fearless in its expression. History has always given, and I think always will give, COPERNICUS a place among the great men of the world.

(To be continued.)

A CLUSTER OF METEORS.

BY SIDNEY D. TOWNLEY.

On Friday evening, 1899, April 7th, at about 8:45 o'clock P. S. T., a very peculiar appearance of meteors was observed at the Students' Observatory of the University of California. While I was looking at the constellation of *Orion*, a whole "flock" of very faint meteors appeared at the same instant, some six degrees to the southeast of *α Orionis*, about in the head of the Unicorn. They were moving northwest, slowly, about parallel to the horizon, and remained visible not more than a second. The "flock" was about one and a half degrees wide, and the path two or three degrees in length. None of the meteors were brighter than a fifth-magnitude star. It was impossible to make an accurate

estimate of the number; there might not have been more than ten, yet, on the other hand, there might have been a hundred.

The phenomenon was witnessed by several other persons. It was public night at the observatory, and after looking at the nebula of *Orion* with the equatorial, we had stepped outside the observatory in order that I might point out to the visitors the location of the nebula. I had just pointed to the constellation, when all exclaimed at once upon the appearance of the meteors. Several other meteors moving in the same general direction were noticed during the evening, but no attempt was made to locate them accurately. From my recollection of their general direction, I should say that the radiant was somewhere in the neighborhood of the constellation *Aries*.

BERKELEY, CAL., April 9, 1899.

PLANETARY PHENOMENA FOR
AUGUST, 1899.

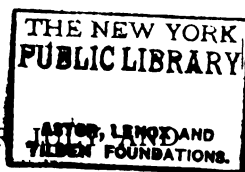
BY MALCOLM MCNEILL.

JULY.

Mercury is an evening star throughout the month, and until the last week it sets more than an hour after sunset, so that it can probably be seen on almost any clear evening in the western twilight. It reaches its greatest eastern elongation on July 22d, and after that date it rapidly approaches the Sun.

Venus is still a morning star, but the interval between its rising and sunrise is growing smaller, and at the end of the month is only a little more than an hour. There will, however, be no difficulty in seeing it in the morning twilight, as the planet is much brighter than *Mercury*. It moves 41° eastward from *Taurus* to the extreme eastern part of *Gemini*.

Mars is still above the horizon in the early evening, but has ceased to be a conspicuous object. It moves 17° eastward and 8° southward from *Leo* into *Virgo*, and on the evening of July 29th passes very close to the third-magnitude star β *Virginis*, the distance being a little greater than the limit of naked-eye separability. At the close of the month the planet's distance from the Earth is more than double the Earth's distance from the Sun.



Jupiter is still in fair position for evening observation in the southwesterly sky. It is on the borders of *Virgo* and *Libra*, and moves about $1\frac{1}{2}^{\circ}$ eastward during the month. It is in quadrature with the Sun on July 24th.

Saturn has reached good position for evening observation, being well above the horizon at sunset. It is in the southern part of *Ophiuchus*, between *Scorpio* and *Sagittarius*, and moves westward about 2° during the month. The rings are at nearly their maximum opening.

Uranus is also well placed for evening observation, being above the horizon until after midnight. It is in the constellation *Scorpio*, and moves about 1° westward. At the close of the month it is 2° east and $1^{\circ} 20'$ south of the third-magnitude star β *Scorpii*.

Neptune is a morning star near the Sun.

AUGUST.

Mercury is an evening star at the beginning of the month, rapidly approaches the Sun, passes inferior conjunction on the morning of August 19th, and becomes a morning star. For the last few days of the month it rises more than an hour before sunrise, and may be seen in the early morning twilight. It is in conjunction with *Venus* on August 21st, but both planets are too near the Sun for naked-eye visibility.

Venus is still a morning star, but is drawing very close to the Sun, and at the end of the month rises less than half an hour before sunrise. It can scarcely be seen during the latter half of the month.

Mars is also nearing the Sun, and at the close of the month it sets about an hour and a half after sunset. This short interval, combined with the planet's great diminution of brightness, will make it very difficult to see after the middle of the month. It is in *Virgo*, and moves 17° eastward and 8° southward, and at the end of the month is 5° west and 4° north of *Spica*.

Jupiter sets about two hours earlier than during the corresponding date in July, and at the end of the month is below the horizon at 9 P. M. It is in *Libra*, and moves 4° eastward and 1° southward toward the brightest star of the constellation.

Saturn remains in good position for observation in the southern and southwestern sky in the evening. It is on the border of *Ophiuchus* and *Scorpio*, and moves very little during the month.

Uranus is also nearly stationary, and keeps its position relative to β *Scorpii*. It sets about an hour earlier than *Saturn*.

Neptune is in *Taurus*, and at the end of the month rises just before midnight.

PHASES OF THE MOON, P. S. T.

			H.	M.			H.	M.
New Moon,	July 7,	12	31	P. M.	Aug. 6,	3	48	A. M.
First Quarter,	July 15,	3	59	P. M.	Aug. 14,	3	54	A. M.
Full Moon,	July 22,	1	41	P. M.	Aug. 20,	8	45	P. M.
Last Quarter,	July 29,	4	42	A. M.	Aug. 27,	3	57	P. M.

THE SUN.

1899.	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° '	H. M.	H. M.	H. M.
July 1.	6 41	+ 23 7	4 40 A.M.	12 4 P.M.	7 28 P.M.
11.	7 22	+ 22 7	4 46	12 5	7 24
21.	8 2	+ 20 29	4 53	12 6	7 19
Aug. 1.	8 46	+ 18 1	5 3	12 6	7 9
11.	9 24	+ 15 16	5 12	12 5	6 58
21.	10 1	+ 12 7	5 21	12 2 P.M.	6 43
31.	10 38	+ 8 38	5 31	12 0 M.	6 29

MERCURY.

July 1.	7 59	+ 22 30	6 1 A.M.	1 22 P.M.	8 43 P.M.
11.	9 4	+ 17 43	6 45	1 47	8 49
21.	9 50	+ 12 20	7 11	1 54	8 37
Aug. 1.	10 16	+ 7 34	7 10	1 36	8 2
11.	10 10	+ 6 23	6 29	12 51	7 13
21.	9 41	+ 9 33	5 10	11 43 A.M.	6 16
31.	9 33	+ 13 13	4 9	10 55	5 41

VENUS.

July 1.	5 11	+ 22 16	3 14 A.M.	10 34 A.M.	5 54 P.M.
11.	6 4	+ 23 10	3 23	10 47	6 11
21.	6 57	+ 22 57	3 37	11 0	6 23
Aug. 1.	7 55	+ 21 25	3 58	11 15	6 32
11.	8 46	+ 18 57	4 20	11 27	6 34
21.	9 36	+ 15 34	4 43	11 37	6 31
31.	10 24	+ 11 28	5 6	11 46	6 26

MARS.

July 1.	10 43	+ 9 13	9 33 A.M.	4 5 P.M.	10 37 P.M.
11.	11 4	+ 6 52	9 24	3 47	10 10
21.	11 26	+ 4 24	9 15	3 30	9 45
Aug. 1.	11 51	+ 1 37	9 6	3 11	9 16
11.	12 13	— 0 58	8 57	2 54	8 51
21.	12 37	— 3 36	8 50	2 38	8 26
31.	13 0	— 6 13	8 43	2 22	8 1

JUPITER.

July	I.	13	55	—	10	27	1	52 P.M.	7	16 P.M.	12	40 A.M.
Aug.	I.	14	1	—	11	11	11	59 A.M.	5	21	10	43 P.M.
Sept.	I.	14	17	—	12	39	10	17	3	34	8	51

SATURN.

July	I.	17	13	—	21	33	5	50 P.M.	10	33 P.M.	3	16 A.M.
Aug.	I.	17	6	—	21	29	3	42	8	25	1	8
Sept.	I.	17	5	—	21	34	1	39	6	22 P.M.	11	5 P.M.

URANUS.

July	I.	16	11	—	20	59	4	47 P.M.	9	32 P.M.	2	17 A.M.
Aug.	I.	16	8	—	20	53	2	47	7	32 P.M.	12	17
Sept.	I.	16	9	—	20	54	12	41	5	26	10	11 P.M.

NEPTUNE

July	I.	5	39	+	22	7	3	37 A.M.	10	57 A.M.	6	17 P.M.
Aug.	I.	5	43	+	22	9	1	45	9	4	4	23
Sept.	I.	5	46	+	22	9	11	46 P.M.	7	5	2	24

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

			H.	M.				H.	M.
I, R,	July	5.	10	33 P.M.	II, D,	Aug.	1.	4	12 P.M.
II, D,		7.	7	2	II, R,		1.	6	28
I, R,		14.	6	57	I, R,		6.	7	10
II, D,		14.	9	39	II, D,		8.	6	49
III, R,		20.	5	53	II, R,		8.	9	5
I, R,		21.	8	51	I, R,		13.	9	4
III, D,		27.	8	26	II, D,		15.	9	26
III, R,		27.	9	52	II, R,		15.	11	41
I, R,		28.	10	46	I, R,		22.	5	28
I, R,		30.	5	15					



NOTICES FROM THE LICK OBSERVATORY

PREPARED BY MEMBERS OF THE STAFF.

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ASTOR, LENOX AND
TILDEN FOUNDATION

REDISCOVERY OF TEMPEL'S SECOND PERIODICAL COMET, ϵ 1899.

This comet was rediscovered by the writer, on May 6th, with the 36-inch refractor. Its position at the time of rediscovery was, —

May, 6^d 21^h 47^m 4^s, G. M. T.; R. A. 18^h 52^m 57^s.78
Decl. — 4° 32' 19".1

This position is very close to that predicted for it by SCHULHOF, in No. 3554 of the *Astronomische Nachrichten*. Following are the very small residuals from the ephemeris:—

Obs.—Comp.: R. A. — 5^s.61; Decl. — 12".9

It is very small and faint, not being over 10" in diameter and 15½–16 magnitude. It is brighter at the center, with some indications of a nucleus.

This comet was first discovered at Milan, by WILHELM TEMPEL, on July 3, 1873, and was soon found to belong to the family of comets having short periods — its period being 5.2 years. It was reobserved in 1878, escaped detection at the next two returns to perihelion, but was again discovered in 1894.

It seems to be growing fainter at each return, if the law of brightness, as expressed by the formula $\frac{1}{r^2 \Delta^2}$, holds even approximately, for at its last observation, in 1878, by TEMPEL, its theoretical brightness was 0.113. In 1894, FINLAY describes it at the time of discovery as eleventh magnitude or fainter, its theoretical brightness on the above assumption being 0.190. At the present apparition its theoretical brightness is 0.475, while its observed brightness is only a fraction of the preceding — 15½–16 magnitude.

* Lick Astronomical Department of the University of California.

It is known that comets do not follow closely this law of brightness, but the deviations in this case seem larger than usual.

The comet's perihelion distance being 1.35, and the Earth being near that longitude at the same time, will cause this apparition to be one of the most favorable possible — the Earth and comet approaching each other to a distance of only thirty million miles.

The disturbing action of *Jupiter* is well illustrated in this case. M. SCHULHOF states that although the comet did not approach *Jupiter* nearer than 1.9 units, the time of perihelion was retarded more than fifteen days.

C. D. PERRINE.

MT. HAMILTON, 1899, May 9.

THE ORBIT OF COMET 1896 III.

Comet 1896 III was discovered by Dr. LEWIS SWIFT, at the Lowe Observatory, on April 13, 1896, [see *Publications A. S. P.*, No. 50, page 93]. During its apparition period, which extended to June 20, 1896, the comet passed through a heliocentric arc of 105° , — 4° before perihelion passage, and 101° after, — and was observed more than four hundred times at thirty-seven different observations.

Having collected all the observations, I combined them into seven normal places, and from the resulting fourteen equations of condition deduced, by the method of least squares, the following most probable set of

HYPERBOLIC ELEMENTS.

$$\begin{array}{lcl} T = 1896, \text{ April } 17.6473143, \text{ G. M. T. } \pm 0^d.0005733 \\ \left. \begin{array}{l} \pi = 179^{\circ} 59' 15''.40 \pm 3''.95 \\ \Omega = 178 \ 14 \ 51 \ .48 \pm 6 \ .74 \\ i = 55 \ 34 \ 24 \ .69 \pm 8 \ .88 \end{array} \right\} \begin{array}{l} \text{Mean Equinox and} \\ \text{Equator of 1896.0} \end{array} \\ q = 0.5662857 \pm 0.00001347 \\ e = 1.0004757 \pm 0.00009985 \end{array}$$

The details of the computation will be found in *Astronomische Nachrichten*, 3550–51.

The interesting element in this orbit is the eccentricity, which shows that the comet's path around the Sun was an hyperbola.

In the few cases where a definitive investigation of a comet's orbit has indicated an hyperbolic curve, doubt has usually been thrown upon the result. In the case of the earlier comets, the

observations were too few, or not sufficiently accurate, to afford a reliable conclusion. In most of the later cases, it has been shown that a parabola, or even a very elongated ellipse, would represent the observations nearly as well as the hyperbola. But there are a few cases of very definite hyperbolic orbits. THRAEN, for instance, found for the Comet 1886 II, the value $e = 1.0002286$, and showed that the hyperbola gave residuals from the observed places only $1/122$ part as large as those given by the best parabola.

Again, STROMGREN found the value of the eccentricity for Comet 1890 II to be 1.0004103 , with a probable error of ± 0.0000130 , or less than one thirtieth of the excess of e over unity. As both of these orbits were based upon ample observational material, it is evident that both comets were moving in hyperbolic arcs,—at least, during their apparition periods.

In the case of Comet 1896 III, I made a careful investigation of the effects of assumed variations of the eccentricity. Determining the variations of the other elements as functions of the variation of the eccentricity, and then assuming for the latter element the successive values 1.00000 (giving the most probable parabola), 1.00024 , 1.0004757 (the definitive value), 1.00064 , and 1.00080 , I found for the sum of the squares of the residuals in the observation equations the values 1677.7 , 965.0 , 732.2 , 843.1 , and 1171.1 , respectively. These residuals clearly showed that no improvement in the orbit could be made by changing the eccentricity, the best possible parabola making the sum of the squares of the residuals more than twice as large as the adopted hyperbola.

I conclude, therefore, that this comet also must be considered to have followed an hyperbolic path during its apparition period, though the figures are not so decisive as in the cases of the two other comets mentioned.

R. G. AITKEN.

May 10, 1899.

GIFT TO COLUMBIA UNIVERSITY OBSERVATORY.

Science announces (April 14, 1899) that Miss CATHERINE WOLFE BRUCE has just given \$10,000 to Columbia University, through Professor J. K. REES, to be expended for the measurement and discussion of astronomical photographs. Miss BRUCE's gifts to the department of astronomy of Columbia now amount to \$22,100.

THREE NEW DOUBLE STARS.

In the course of my double-star observations in the past few months I have found the following new pairs :—

Cambridge (Eng.) A. G. 3993.

			7 ^h 24 ^m 5 ^s	+ 28° 6′	
				^{Mags.}	
1898.890	254°.6	2″.07	8.5	— 12.5	36-inch.
.922	255°.9	2.21	9.0	— 13.0	"
1898.91	255°.2	2″.14	8.8	— 12.8	

This pair is 29' following and 1' south of 65 *Geminorum* (β1174).

DM + 31° 1982.

			9 ^h 20 ^m 19 ^s	+ 31° 35′	
				^{Mags.}	
1899.286	43°.6	0″.94	8.7	— 9.5	12-inch.
.303	47°.7	0.77	8.7	— 10.0	"
.380	43°.6	0.91	8.8	— 11.0	36-inch.
1899.32	45°.0	0″.87	8.7	— 10.2	

This pair was found while looking for Ho.366, which is 25' following and 24' north of it.

L.L. 21535.

			11 ^h 11 ^m 44 ^s	— 4° 36′	
				^{Mags.}	
1899.303	343°.5	0″.67	8.8	— 9.0	12-inch.
.358	338°.8	0.66	8.5	— 9.0	"
.360	335°.9	0.68	8.5	— 9.0	36-inch.
1899.34	339°.4	0″.67	8.6	— 9.0	

The 36-inch telescope also shows a fourteenth-magnitude companion 37″.5 distant from the close pair in the position angle 7°.5.

The star places are given for 1900.0.

R. G. AITKEN.

May, 1899.

MEASURES OF *SIRIUS*.

Two measures of the companion to *Sirius* made this season with the 36-inch telescope give the following positions :—

1899.177	154°.3	4″.55	weight 4
.254	155°.6	4″.34	" 4

The distance is slowly increasing, though not so rapidly as the published orbits indicate, and the star is much easier to measure than it was a year ago.

R. G. AITKEN.

SOME NEW SPECTROSCOPIC BINARY STARS.

In the progress of the determination of stellar velocities in the line of sight with the Mills spectrograph, three additional spectroscopic binary stars have been discovered.

ζ *Geminorum*. ($\alpha = 6^h 58^m$; $\delta = +20^\circ 43'$.)

About twenty-five spectrum plates of this well-known variable star have been obtained and reduced. The observed velocities are included between the limits $+24$ and -5 kilometers per second; the positive sign indicating recession from the solar system, and the negative sign approach. The period of the light variations of ζ *Geminorum* is 10.154 days. The spectroscopic observations show that this is identical with the period of revolution of the bright star around its invisible companion.

ι *Pegasi*. ($\alpha = 22^h 02^m$; $\delta = +24^\circ 51'$.)

The partial reductions of four spectrum plates of this star yield the following velocities, of approach:—

1897, October	7,—51 km.
1898, August	19,—45
	29,—37
September 28,—	22

The period of revolution is undetermined.

θ *Draconis*. ($\alpha = 16^h 00^m$; $\delta = +58^\circ 50'$)

Four plates of this star's spectrum give the following approximate velocities:—

1898, March 23,	$+16$ km.
April 6,—	34
1899, April 8,	$+10$
April 10,—	16

The period of revolution is undetermined.

W. W. CAMPBELL.

ASTRONOMICAL TELEGRAM.

(*Translation.*)

Lick Observatory, May 7, 1899.

To Harvard College Observatory: (Sent 5:50 P.M.)

Comet Tempel was observed on its return by Mr. C. D. PER-
RINE on May 6.9077, G. M. T., in R. A. $18^h 52^m 57^s.8$; Decl.

0 - - - -"

NEW TELESCOPE FOR THE WESTERN RESERVE UNIVERSITY.

The Cleveland *Plain Dealer*, under date of March 18, 1899, announces that Messrs. W. R. WARNER and AMBROSE SWASEY, of the firm of WARNER & SWASEY, well-known as builders of telescopes, have presented to the Western Reserve University an equatorial telescope and accessories and dome. The dome will be constructed on the southeast corner of the physical laboratory building, and will be about seventeen or eighteen feet in diameter. The telescope is to have a 10-inch object-glass with a focal length of about thirteen feet, and is to be completely equipped with all necessary apparatus. The work of construction is already going on, and the necessary changes for the erection of the dome will be made at once.

THE CHARLES SMITH SCOTT OBSERVATORY.

The Park College *Record*, for March 26, 1899, contains an illustrated account of the Observatory given to Park College (Parkville, Mo.), by Mr. ANTHONY DEY, as a memorial to his uncle, Judge SCOTT, of New Brunswick, N. J. The building is a handsome stone structure, and houses an 8-inch equatorial, fully supplied with the usual accessories, a combined transit and zenith telescope, a fine sidereal clock, and a chronograph. These instruments, except the clock, were all built by Messrs. WARNER & SWASEY, and constitute an excellent equipment for student instruction in astronomy. Professor A. M. MATTOON, who is a member of the Astronomical Society of the Pacific, is director of the observatory.

OBSERVATION OF THE WATSON ASTEROIDS AT THE LICK OBSERVATORY.

At the request of the Watson Trustees, the Lick Observatory has undertaken to reobserve the asteroids discovered by Professor JAMES C. WATSON. Observations of (105) *Artemis* and (139) *Juerra*, by Mr. CODDINGTON and Mr. ROSS, have already been printed in the *Astronomical Journal*. Nine more of these asteroids have been found and observed by Mr. CODDINGTON. The two 6-inch portrait lenses and the 12-inch equatorial are the instruments used for this work.

J. E. K.

DEATH OF MISS E. BROWN.

“The news of the death of Miss ELIZABETH BROWN on the evening of Sunday, March 5th, came as a very great shock to her numerous friends. For several years past Miss BROWN has been a leading figure in amateur astronomy, and to her special department—the drawing and description of solar spots and faculæ—she devoted a large part of the last years of her life. She contributed her first paper to the Liverpool Astronomical Society on the ‘Proper Motion of Sun-spots’ on 1883, December 17, and was asked to become Director of the Solar Section of that society very shortly after its inception. After the dissolution of the Liverpool society she was very anxious that an astronomical association on similar but wider and firmer lines should be formed, and when the British Astronomical Association, in 1890, filled this want she became Director of its Solar Section, and an ardent worker, not only in her own but in several other of the sections, notably those for the observation of the Moon, of colored and of variable stars. She was a frequent attendant at the meetings of the Royal Astronomical Society. She was a Fellow of the Royal Meteorological Society, and one of her observatories at Cirencester was devoted to meteorological instruments, where she continued the observations of her father, the late Mr. THOS. C. BROWN.

“Though by no means robust, she went on three long and arduous eclipse expeditions—to Russia, to Trinidad, and to Lapland. On only one of the three was she favored by a clear sky; but the fruitless expedition to Russia in 1887 and the fruitful one to Trinidad in 1889 were commemorated by two beautifully and vividly written narratives,—‘In Pursuit of a Shadow,’ and ‘Caught in the Tropics.’ She was even now making preparations to go on a fourth eclipse expedition, to Spain or Africa. Those of her friends who are looking forward to the same expedition will no doubt feel that it has lost much of its pleasure by her absence.”

A. S. D. M.

THE OBSERVATORY, April, 1899.

[To the above note we may add that Miss BROWN’s interest was not limited to the astronomical work in her own country. She was a life member of our own society, joining in September, 1890. We should also add that it is stated in *Science* that, in her will, Miss BROWN has left one of her observatories and

all its contents (probably the one containing the apparatus for solar observations) and £1,000 to the British Astronomical Association.]

SOME RECENT ASTRONOMICAL PUBLICATIONS. .

PUBLICATIONS OF THE CINCINNATI OBSERVATORY, No. 14.
Catalogue of 2030 Stars for the Epoch 1895. By JERMAIN
G. PORTER, A. M., Ph. D., Director. Cincinnati, 1898.

The catalogue contains the results of five years' work (1893-98) with the Cincinnati meridian-circle. The working-list was made up primarily of known proper-motion stars, and the proper motions derived from a least-squares adjustment of all available material are given in the catalogue.

DIE VENUS-DURCHGÄNGE, 1874 UND 1882. Bericht über die
Deutschen Beobachtungen, ... herausgegeben von
A. AUWERS Erster Band. Berlin, 1898.

With the publication of this volume the work of the German Transit of Venus Commission is closed. Volumes II to VI, previously published, contain full details of the observations made in 1874 and in 1882, and the complete discussion of the results obtained. The present volume gives the history of the enterprise and the documentary record of the proceedings of the Commission.

In an appendix it also gives an account of some observations of the great comet of 1882, made by two of the parties during the ocean voyage to the observing stations, and some plates which reproduce the drawings of the comet made by Herr SCHWAB.

ASTRONOMICAL PAPERS, PREPARED FOR THE USE OF THE
AMERICAN EPHEMERIS AND NAUTICAL ALMANAC. Vol.
VIII, Part II. Catalogue of Fundamental Stars for 1875
and 1900; Reduced to an Absolute System. Prepared by
and under the direction of SIMON NEWCOMB. Washington,
1898.

In his introduction, Professor NEWCOMB states that this catalogue was first undertaken in 1895, in consequence of a widely expressed desire by official and private astronomers in the United States for an improvement in the star-list of the American Ephemeris. At the Paris Conference of 1896, Professor NEWCOMB was requested to complete the work in a form suitable for international use in astronomical ephemerides generally. This

required a considerable addition to the number of stars included, and led the author to base the work on more material than it was intended to use at the commencement. As now completed, the volume contains a complete discussion of the material available, the methods to be used in reducing and combining the star-places to form the adopted system of Right Ascensions and Declinations, and finally the catalogue of 1596 fundamental stars for 1875 and 1900, with full data for reducing these positions to any other desired epoch.

CATALOGUE DE 4281 ÉTOILES ENTRE $74^{\circ} 40'$ et $80^{\circ} 20'$ de DÉCLINAISON BORÉALE 1855 POUR L'EQUINOXE DE 1875.
... par DMITRI DOUBIAGO. Leipzig, 1898.

This volume forms Part I of the catalogue of the Astronomische Gesellschaft of stars to the ninth magnitude between $+80^{\circ}$ and -2° Declination. In addition to the 2322 stars of ninth magnitude, or brighter, it contains nearly as many more of the fainter stars. The observation of this zone was undertaken at Kasan by Professor M. KOWALSKI in 1869, and was completed by his successor, Professor DOUBIAGO.

TABLES OF THE HELIOCENTRIC MOTION OF MARS. By SIMON NEWCOMB. Washington, 1899.

These tables form Part IV of Volume VI of the Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, and complete the author's work on the "Motions of the Four Inner Planets."

AN INTRODUCTION TO STELLAR ASTRONOMY. By W. H. S. MONCK, M. A., F. R. A. S. With Illustrations. London: HUTCHINSON & Co. 1899.

The book contains chapters on the nature and distances of the fixed stars, their magnitudes, motions, spectra, etc., most of which have already been printed in *Popular Astronomy*, but here appear as revised and corrected by the author, and with some additions. The illustrations are from some of the well-known photographs taken by Dr. ISAAC ROBERTS.

STARS AND TELESCOPES: A Handbook of Popular Astronomy. Founded on the ninth edition of LYNN's Celestial Motions. By DAVID P. TODD, M. A., Ph. D., Boston: LITTLE, BROWN & Co. 1899.

The general character of this work is indicated by the title and in the preface, which states that "Stars and Telescopes is

intended to meet an American demand for a plain, unrheterical statement of the astronomy of to-day; and it has been based upon Mr. LYNN'S *Celestial Motions* because his little book had already covered excellently part of the ground, and had passed through nine English editions." Professor TODD'S additions are printed in different type, and "with a single exception, the ample illustrations are wholly new additions."

MEDALS AWARDED BY THE NATIONAL ACADEMY OF SCIENCES.

At the annual meeting of the National Academy of Sciences, held in Washington, on April 18 to 20, 1899, the Watson Gold Medal was awarded to Dr. DAVID GILL, Director of the Royal Observatory at the Cape of Good Hope; and the Henry Draper Gold Medal to Professor JAMES E. KEELER, Director of the Lick Observatory. This is the first award of the Henry Draper Medal since 1892.

REDISCOVERY OF HOLMES'S COMET.

This interesting comet was rediscovered by the writer on the morning of June 11th with the 36-inch refractor. The comet is very faint — about 16th magnitude. It is about 30" in diameter, and very slightly brighter at the middle. It was found very close to the place assigned to it by ZWIERS, in No. 3553 of the *Astronomische Nachrichten*, the residuals being but $+28'$ in α , and $+4'54''$ in δ (O — C). C. D. PERRINE.

LIBRARY NOTICE.

Arrangements are being made to keep the Library of the Society open to members and visitors on three afternoons of each week between the hours of 2 and 5, until the 15th of August. Information as to the exact days, and other details, may be obtained at the rooms of the Society, at 819 Market Street, San Francisco.

THE LIBRARY COMMITTEE.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD AT THE LICK OBSERVATORY, JUNE 10, 1899.

Dr. KEELER presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected :—

LIST OF MEMBERS ELECTED JUNE 10, 1899.

Major S. COMFORT	{ Standard Oil Co. of New York, Bombay, India.
Mr. MICH. MULLANY	{ N. W. cor. Washington and Scott Sts., S. F., Cal.
Dr. W. SEWARD WEBB	{ Grand Central Station, New York, N. Y.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD AT THE LICK OBSERVATORY,
JUNE 10, 1899.

Dr. KEELER presided. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented :—

1. The Rise and Progress of Astronomy in Central Europe, by Dr. S. D. TOWNLEY.
2. Planetary Phenomena for July and August, 1899, by Prof. M. McNEILL.
3. Clock-Rates and Barometric Pressure, by Ensign EVERETT HAYDEN, U. S. Navy.
4. A Cluster of Meteors, by Dr. S. D. TOWNLEY.

Dr. TOWNLEY gave a short description of a cluster of meteors which he had observed.

Dr. KEELER exhibited some recent photographs taken with the Crossley Reflector.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. GEORGE C. PARDER	President
Mr. JAMES E. KEELER	First Vice-President
Mr. CHARLES BURCKHALTER	Second Vice-President
Miss R. O'HALLORAN	Third Vice-President
Mr. C. D. PERRINE	Secretaries
Mr. F. R. ZIEL	
Mr. F. R. ZIEL	Treasurer
<i>Board of Directors</i> —Messrs. BURCKHALTER, CAMPBELL, HILL, KEELER, MOLERA, Miss O'HALLORAN, Messrs. PARDER, PERRINE, PIERSON, VON GELDERN, ZIEL.	
<i>Finance Committee</i> —Messrs. PIERSON, VON GELDERN, HILL.	
<i>Committee on Publication</i> —Messrs. AITKEN, TOWNLEY, VON GELDERN.	
<i>Library Committee</i> —Messrs. TOWNLEY, GEO. C. EDWARDS, Miss O'HALLORAN.	
<i>Committee on the Comet-Medal</i> —Messrs. KEELER (<i>ex-officio</i>), PIERSON, BURCKHALTER.	

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

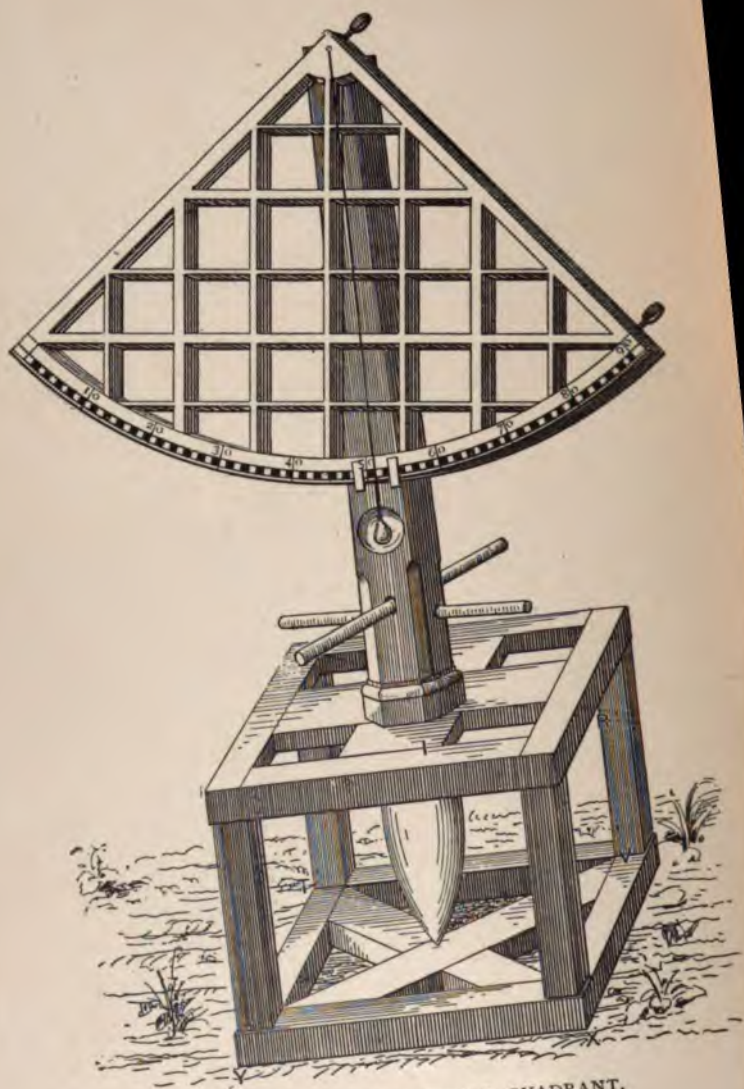
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)





TYCHO BRAHE'S OUTDOOR QUADRANT.
(SEE PAGE 139.)

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XI. SAN FRANCISCO, CALIFORNIA, AUGUST 1, 1899. No. 69.

THE RISE AND PROGRESS OF ASTRONOMY IN
CENTRAL EUROPE.—II.

BY SIDNEY D. TOWNLEY.

The work of COPERNICUS, after his death, was taken up by ERASMUS REINHOLD (1511 to 1553), professor of mathematics at Wittenberg, who checked and corrected all the calculations of COPERNICUS, and computed a new set of tables, known as the Prutenic tables. These were published in 1551; and as they gave the positions of the heavenly bodies more accurately, they soon displaced the ancient Alphonsine tables.

The next great name in the astronomy of Central Europe is that of TYCHO BRAHE. The life of this strange and wonderful man has been written many times. His work, however, was epoch-making in the history of practical astronomy, and cannot be passed over hurriedly.

TYCHO BRAHE (1546 to 1600), eldest son of a Danish nobleman, was born at Kundstrup, in the southern part of the Scandinavian peninsula, then a portion of Denmark. He studied law at the universities of Copenhagen and Leipsic, but became interested in astronomy through observing a predicted eclipse of the Sun, August 21, 1560. It was the prediction more than the eclipse that interested him. Even at that early age he was struck with wonder at the power of a science by which such events could be accurately foretold. From that time on much of his attention was given to the study of astronomy.

For several years after leaving Leipsic TYCHO lived an undecided life, his time being divided between Germany and his native country, his studies between astronomy and alchemy. His attention was finally fixed upon astronomy by the appearance of the new star in 1572. His work upon this attracted much notice and

brought him fame. In 1576, King FREDERICK II. gave him an estate, a pension, and one hundred thousand dollars to build and equip an observatory on the island of Hveen, situated fourteen miles to the northeast of Copenhagen. This observatory was equipped with by far the finest instruments ever constructed up to that time. Here TYCHO labored for twenty years, and reared for himself a lasting monument in the great number of magnificent and accurate observations there made. TYCHO was no respecter of persons, however, and although the most eminent man of science in Europe, yet he made many enemies, and when King FREDERICK died TYCHO left Denmark after five years of persecution. With his family and instruments, he went back to Germany, and finally settled in Prague, where Emperor RUDOLPH II. gave him a castle. Here little was done, however; for in a few years TYCHO died, at the age of fifty-four years.

Thus, in brief, is an outline of TYCHO BRAHE's life. Many of its details have been preserved; and as he was in many respects a peculiar man,—we might almost say eccentric,—some of the details are very interesting. It is my purpose, however, to deal with his contributions to science rather than with personal incidents.

TYCHO's observations were commenced during his student days at Leipsic. His first instrument was a pair of compasses. By holding these near the eye and pointing one leg at a star and the other at a planet, he was able to obtain the angular distance between the two bodies; and by measuring the angular distance of the planet from two or more known stars, he could determine the position of the planet. Even with such a crude instrument he was able to ascertain that the positions of the planets were not well represented by either the Alphonsine or the Prutenic tables, TYCHO's first recorded observation was made, 1563, August 17.

The next instrument used by TYCHO was a cross-staff. Two straight, graduated pieces of wood were placed at right angles to each other, the shorter one movable upon the longer. A fixed sight was placed at the right angle and a movable sight on the shorter arm. The method of using the instrument was as follows: The shorter arm was first set at an arbitrary mark on the longer arm; then, holding the instrument in the plane passing through the two bodies and the observer's eye, the eye being at the end of the longer arm, the observer sighted along the longer arm and through the fixed sight at one body and from the end of the longer

arm through the movable sight, or along the hypotenuse of the right-angled triangle, to the second body. The graduation on the arms gives the base and perpendicular of a right-angled triangle; and it is, of course, a simple problem to compute the angle at the eye or the angle between the two bodies. It is easy enough to see that such an instrument is a very crude affair. Still TYCHO soon discovered that the divisions upon his did not give the angles correctly. Not being able to obtain the money to purchase a new one, he set to work to construct a table of corrections, to be applied to the readings of his instrument to give the true angles. This point is worthy of emphasis, as I believe it was the first time such a thing had been done. Ancient observers had always considered their instruments perfect, and had taken without question the results given by them. Now, one of the most important steps in astronomical observations is to determine the instrumental errors, and to make allowance for them in deducing the results.

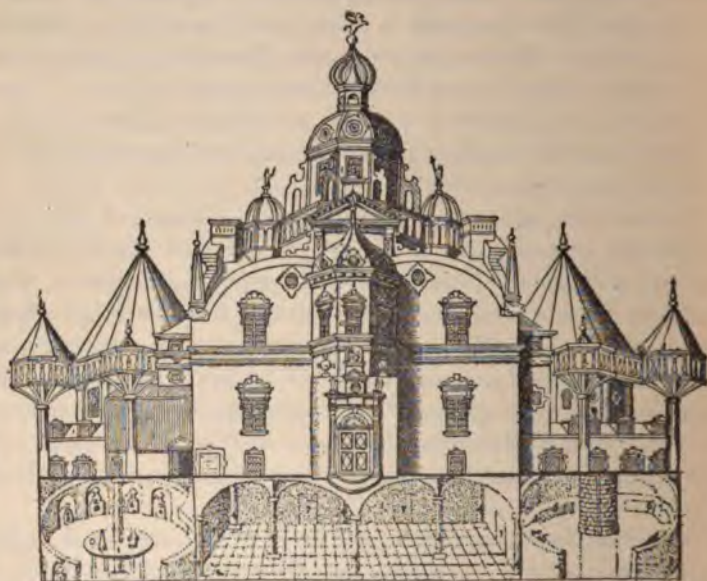
TYCHO did not enter seriously into the business of observing before the observatory was built on the island of Hveen. Some scattering observations were made at home in Denmark and at different places in Germany. At Augsburg he constructed a huge quadrant, a cut of which is shown in frontispiece.* It was a massive affair, made of oak, with an arc of brass. The radius of the circle was fourteen cubits, or about nineteen feet. The manner of using it is evident from the cut. It stood in the open air, but was unfortunately destroyed by a storm after a short life of five years.

Another instrument designed by TYCHO, and used in his earlier observations, was a sextant. This consisted simply of two arms of wood about five and one half feet long, joined together with a hinge at one end and connected near the other by an arc of 30° . A sight was placed upon each arm.

After giving his attention for some time to studies of a chemical and medical nature, TYCHO's energies were finally turned for good to the science of astronomy by the appearance of the new star in *Cassiopeia* in 1572. This was the first phenomenon of this nature recorded since the time of HIPPARCHUS. The star was already of great brilliance before it was noticed by TYCHO. The

* At the end of this series of articles a list of reference works will be given. It is only just to say here, however, that two of the cuts here reproduced and much of the material for this article were taken from J. L. E. DREYER's most excellent work, "Tycho Brahe." The other two cuts are taken from "Pioneers of Science," by OLIVER LODGE.

observations taken were in some respects different from those now made on a new star. Such phenomena were, of course, very imperfectly understood. Many supposed the new star to be a comet without a tail, and comets were then thought to be effusions in the Earth's atmosphere. Of all those who concerned themselves with this new star, TYCHO seems to have been about the only one to approach the matter in a scientific way. He saw that a few well-directed observations would be worth more than all the theories the human brain could concoct. He not only observed the changes in brightness and color of the star, but carefully



URANIABORG.

measured, with a sextant, during the several months it remained visible, its distance from the principal stars of *Cassiopeiæ*. These distances did not change, thus showing the body to be neither of a planetary nor cometary nature. He also observed its distance from *Schedir* at upper and lower culmination, to detect if possible any parallax. Of course, none was found, thus showing that the body was not in the sphere of the Moon. It also twinkled like other stars, and TYCHO's conclusion was that it belonged to the eighth sphere, or the sphere of the fixed stars. TYCHO drew up a manuscript of his observations and conclusions, and after no such

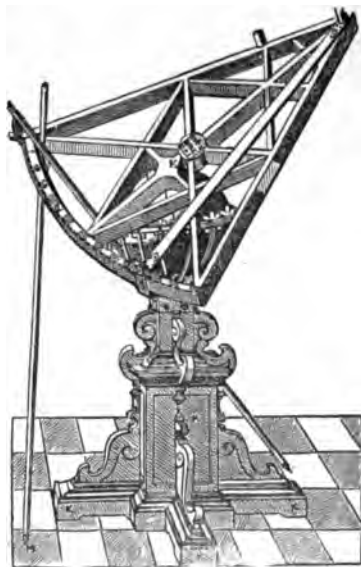
hesitancy (it was then considered beneath the dignity of a nobleman to publish books) and considerable urging by his friends, he consented to allow the manuscript to be published. The title is a long and imposing one, and only a few copies of the book now exist. It was afterwards republished in his work, *Astronomiæ Instauratæ Progymnasmata*.

After giving his observations and conclusions, TYCHO goes on to treat of the astrological aspects of the new star phenomenon. Although an interesting subject, and although intimately connected with the astronomy of that date, still I shall not enter into that phase of the subject now.

The foundation-stone of Uraniaborg was laid, with appropriate ceremonies, on the 8th of August, 1576. The building was of the Gothic-Renaissance style, and something of the general plan may be seen from the cut here reproduced. Later (1584) a second observatory, Stjernborg, was erected a short distance from Uraniaborg. In this the observing-rooms were underground, to protect the instruments from the wind.

In all there were twenty-eight instruments in the two observatories. The instruments most used were quadrants, sextants, and armillæ spheres. The first two types have already been described. Quadrants were used by the ancients, although TYCHO attached horizontal circles to some of his with which to measure azimuths. TYCHO supposed himself to be the inventor of the sextant; but the instrument is said to have been used many hundred years before by the Arabs. TYCHO had several of these instruments; some of them were quite large, one having a radius of five and one half feet. Of course, they were mounted upon stands.

The armillæ were of two types, the ancient zodiacal armillæ, for measuring latitudes and longitudes, and the equatorial armillæ.

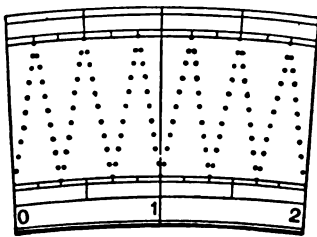


SEXTANT.

Instruments of the former type were but little used by TYCHO, but those of the latter type were among his principal instruments. One consisted of three circles of steel, meridian and equator firmly fixed together, and a movable declination-circle. Movable sights were placed on the equatorial and declination circles, while an object-sight was fixed on the polar axis at the center of the sphere. It is easy to see how the declination and hour-angle of a body could be measured with this instrument. Another, considered by TYCHO as one of his most accurate instruments, consisted of a declination-circle nine and one half feet in diameter and a semicircle representing the position of the equator, below the horizon. It was provided with appropriate sights, and the polar axis could be adjusted in inclination and azimuth, by means of screws.

Besides these chief instruments, there were many minor ones, such as globes, cross-staffs, and one of historic interest, a triquetrum, made and used by COPERNICUS. With three exceptions, all the instruments were made under TYCHO's direction in the workshop on the island. The most skilled workmen were employed and the greatest of care was used in the construction of the instruments.

It was, however, not alone the excellence of the instruments that enabled TYCHO and his assistants to make observations so vastly superior to any previously made. Two devices on the instruments added greatly to the accuracy attainable. The devices aided in sighting upon the object and in reading the circle.



TRANSVERSALS,

Before TYCHO's time it was customary to attach a pinule, with a small hole in it, to each end of the alidade and to sight through these holes. If the hole were small faint objects could not be seen, while if the hole were large the errors of setting were large. TYCHO substituted for holes a system of adjustable slits, by

which very accurate pointings could be made. The other device was the method of transversals, which aided in reading the circles. Although not original with TYCHO, still he was the first to make extensive use of this method. The arc was divided upon both the outer and inner circumferences. The transverse line from

the end of an outer division to the end of the next following inner division was divided into, say, ten equal parts, and so on. We at once see that if the circle were divided to ten minutes, it could thus be read directly to minutes. These two devices enabled TYCHO to make observations several times more accurate than any previously made. Several clocks were also among the instruments at Uraniaborg; but as they were not very good ones, they were used but little.

The work of the great astronomer at Hveen soon became known, and many students came from all parts of Europe to act as assistants in the observatory. Many observations were made by them. The observations, of course, were all of one kind — observations of position. The Sun, Moon, planets, and comets were systematically observed, and a catalogue of nearly a thousand stars was made.

The observations of the Sun consisted chiefly in taking his meridian altitude with several different instruments. The equinoxes of 1584–88 were observed and the time of arrival of the Sun at points 45° from the equinoxes. From these data TYCHO deduced anew the longitude of the apogee, its annual motion, the eccentricity of the solar orbit, and the greatest equation of the center. Solar tables were also constructed, which were found to be much more accurate than either the Alphonsine or Prutenic tables. The length of the tropical year was deduced by comparing TYCHO's observations with those of WALTHER, made at Nuremburg, and a value about one second too small obtained.

During early years TYCHO paid but little attention to the Moon. Later, however, systematic observations were made of this body, and several inequalities in longitude and latitude discovered; a more accurate determination of the inclination of the lunar orbit was also made, and the non-uniform retrogression of the nodes was found. Lunar and solar eclipses were regularly observed.

The planets were especially observed by TYCHO from his youth to the end of his career. A great mass of material was accumulated, but TYCHO did not live to deduce the results from these observations. From the standpoint of the advancement of science, it is perhaps not to be regretted that the working up of the observations was left to another. TYCHO certainly would have used his observations to try and prove the truth of his false theory of the solar system; while in the hands of KEPLER, a

believer in the Copernican system, they were made to bring forth those three famous laws, and to place before the world the true system of the Sun and planets.

Seven comets appeared during TYCHO's career, the most brilliant of them appearing in 1577. TYCHO's observations of these bodies were similar to those made by him upon the new star in 1572. These observations showed that comets possess no parallax measurable with the instruments then in use, thus removing them far beyond the confines of the Earth's atmosphere, where they had been placed by the philosophy of ARISTOTLE. This perhaps is not one of the least of TYCHO's contributions to science.

TYCHO's early observations of comets and the new star of 1572 showed him the necessity of more accurate positions of the fixed stars, and he therefore set about compiling a new catalogue of stars as soon as possible after the completion of his observatory. No catalogue of stars had been published since the time of PTOLEMY, and his was probably mainly a reproduction of the still older one compiled by HIPPARCHUS. In determining the longitude of a star HIPPARCHUS used the Moon as a stepping-stone from the Sun to the star; but TYCHO adopted the method of WALTHER, of using *Venus* instead of the Moon, on account of her smaller parallax, slower motion, and smaller diameter.

In 1582, *Venus* was so situated that she could be observed in full daylight for several weeks, and her distance from the Sun could then be measured at a time when both bodies were sufficiently far from the horizon to make errors of the adopted refractions small. The distance between the Sun and *Venus* was measured with a sextant, and at the same time their Declinations were taken with armillæ. These data give the three sides of a spherical triangle, the solution of which gives the angle at the pole between the hour-circles of the two bodies or the difference of their Right Ascensions. The Right Ascension of the Sun being taken from the tables, that of *Venus* becomes directly known. Often altitudes and azimuths of the bodies were taken also. After sunset the same program was carried out between *Venus* and some bright star near the Zodiac, thus giving the Right Ascension of the star, provided the motion of *Venus* between the two sets of observations is taken into account. The Declination was measured directly. In this way the Right Ascensions of several stars around the Zodiac were determined. Each of these stars was then connected by distance measures with

α *Arietes*, each thus giving an independent determination of the Right Ascension of that body. This program was repeated on several different years, both when *Venus* was east and west of the Sun. In all, fifteen determinations of the Right Ascension of α *Arietes* were made, and agreed remarkably well among themselves. α *Arietes* thus became the fundamental star of the system, and the Right Ascensions of other stars were determined directly or indirectly from it by distance measures and the solution of spherical triangles. In this way a catalogue of nearly eight hundred stars was made. This catalogue was printed in his work, *Progymnasmata*, and reprinted by KEPLER in the *Tabulæ Rudolphinæ*, in 1627, and by BAILY in "Memoirs Royal Astronomical Society," (Vol. XIII.)

Another important contribution to practical astronomy was TYCHO's investigations upon the subject of atmospheric refraction. The phenomenon of refraction was discovered by PTOLEMY in the second century of the Christian era, but no observer before TYCHO ever constructed a table of refractions or corrected observations for this source of error. TYCHO constructed a table of refractions for different altitudes by taking the difference between observed and computed altitudes of the Sun. A similar table was constructed in the same way for the fixed stars, but there was considerable of a difference between the two tables, due to the fact that in reducing the observations of the Sun an erroneous value of the solar parallax ($3'$) was used. This is the only astronomical constant that TYCHO took from his predecessors, and it was perhaps more widely wrong than any other. It seems strange that he should never have suspected that the difference between the solar and stellar refractions was due to this cause.

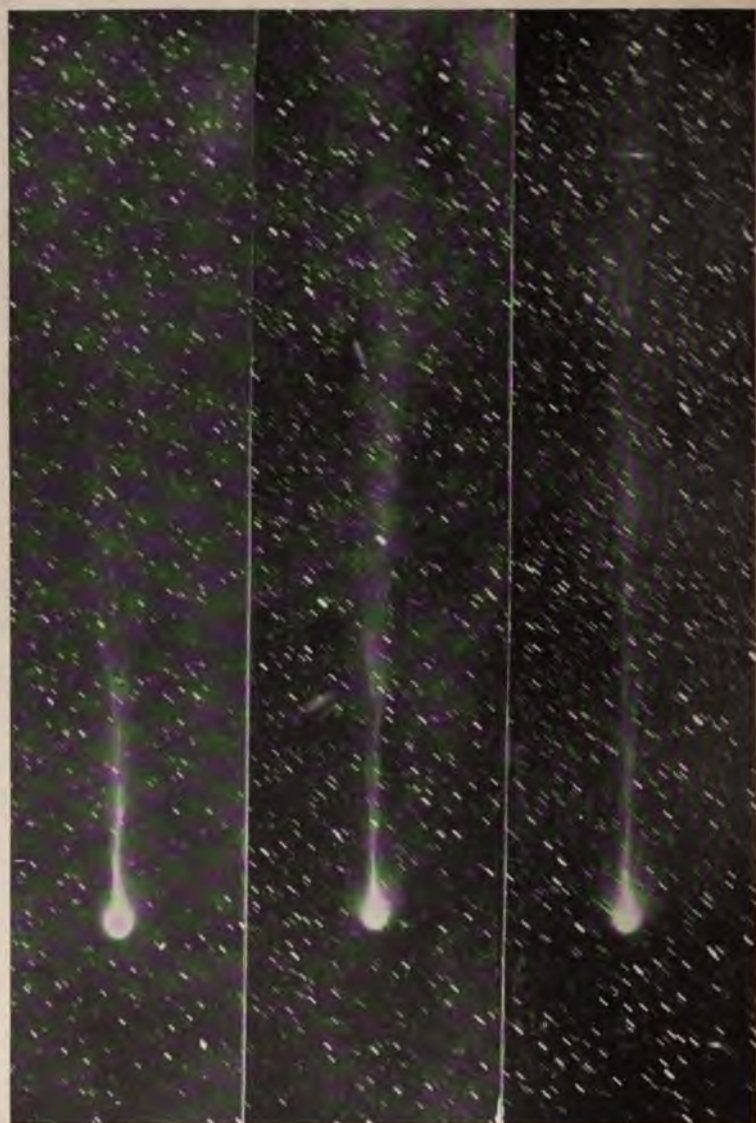
But little was accomplished by TYCHO after leaving Denmark. A portion of the instruments were set up near Prague, but few observations were taken with them. After TYCHO's death they were purchased by the Emperor, stored in a cellar, and all save the great globe were destroyed in the rebellion of 1619. The globe, after many wanderings, was finally taken to Copenhagen and unfortunately destroyed in the great fire of 1728. There now remains, as far as known, no vestige whatever of TYCHO's celebrated instruments. The observatory at Hveen was soon allowed to decay after TYCHO's departure, and now nothing remains but a mound of earth to mark the spot where this temple of science once stood.

Many of TYCHO's manuscript observations are now deposited in the Royal Library in Copenhagen. His principal published books have already been mentioned. *Astronomia Instauratæ Mechanica*, an illustrated description of the principal instruments of the observatories at Hveen was issued in 1598. A reprint was issued in 1602. The other work, *Astronomiæ Instauratæ Progymnasmata*; or, Introduction to the New Astronomy, was only printed in part before TYCHO's death. It was designed in this to give all of his investigations which led up to an exposition of his theory of the solar system and to the construction of planetary tables. The first volume related to the new star of 1572; the second volume to the comet of 1577. Other volumes were to treat of precession, refraction, motion of Sun, lunar theory, etc. Some of these were later printed by KEPLER.

We have thus given in brief an account of the principal achievements of TYCHO BRAHE. I have dwelt upon them because they mark the beginning of modern practical astronomy. TYCHO's methods were thoroughly scientific, the advance over the work of all predecessors was great, and it was there on that little island in the sea that the firm foundation was laid.

TYCHO must have been a man of great energy. A great mass of observations was accumulated by him; but, of course, we must not overlook the fact that he had many assistants who took part in the observations. It is not, however, so much the quantity as the quality of the observations that calls for our admiration. Indeed, when we consider the fact that he had neither telescope nor vernier, we sometimes marvel at the accuracy attained in the observations.

Eminently successful as a practical astronomer, TYCHO did not attain eminence in a theoretical line. He could accept neither the Copernican nor the Ptolemaic theory of the solar system, but constructed a compromise between the two. Perhaps little need be said of this theory. It made but few converts and fortunately died with its originator. Nevertheless the life work of TYCHO is certainly not less eminent, but perhaps more eminent, than that of COPERNICUS, for it is certain that KEPLER could not have worked out the true system of the universe without TYCHO's observations; whereas, he might have done so had the theory of COPERNICUS never been promulgated. Still the works of each were great, and perhaps too unlike to be compared; not more



May 8, 1899.
14^h 20^m to 15^h 30^m.

May 9, 1899.
14^h 8^m to 15^h 30^m.

May 10, 1899.
14^h 4^m to 15^h 32^m.

COMET α 1899 (SWIFT).
(Photographed by E. F. CODDINGTON.)

unlike, however, than the men themselves. "COPERNICUS was of humble origin, and certainly not wealthy; TYCHO BRAHE was of noble birth, and inherited great riches. COPERNICUS loved solitude and rest; TYCHO BRAHE restlessly moved from place to place all over Europe. COPERNICUS was calm and peaceful in disposition; TYCHO BRAHE was a man of violent temper. COPERNICUS was always tender to the prejudices of others; TYCHO BRAHE delighted in attacking false beliefs. They resembled each other in one point alone — the patient carefulness of their researches, and the strenuous earnestness of their lives."

(To be continued.)

PHOTOGRAPHIC OBSERVATIONS OF COMET *a* 1899 (SWIFT).

BY E. F. CODDINGTON AND H. K. PALMER.

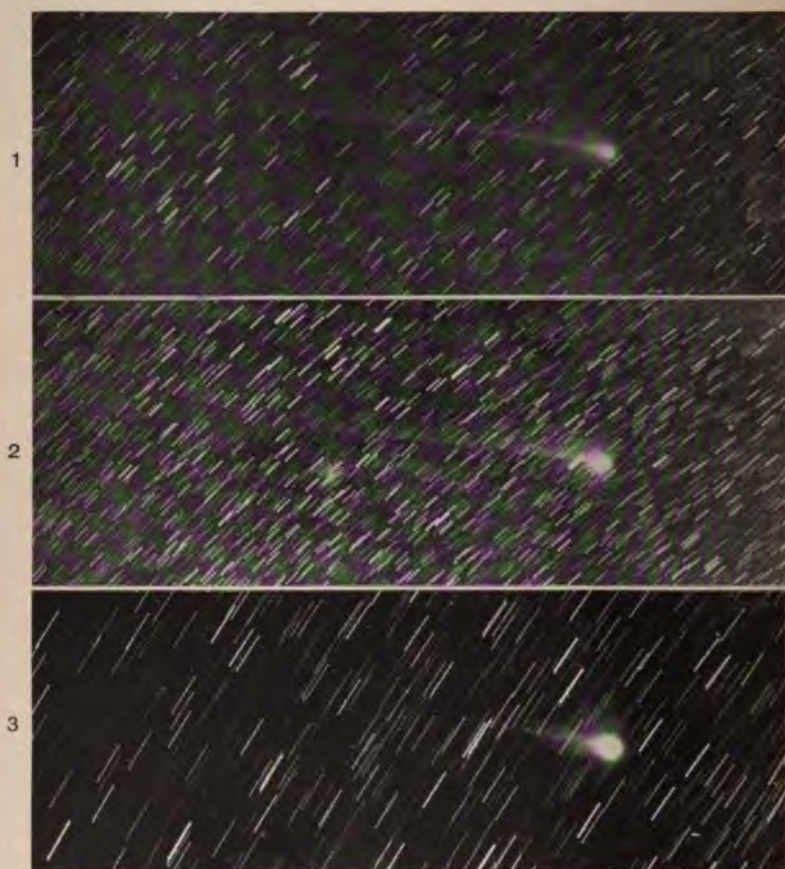
At the time of its discovery this comet was too near the Sun to be photographed. But after it had passed perihelion it became a morning object, and its apparent distance from the Sun rapidly increased. It was then photographed with two instruments at the Lick Observatory, on every suitable night from May 6 to June 13, 1899, inclusive. In all, thirty negatives were obtained. Of these, nine were taken by Mr. CODDINGTON with the Crocker photographic telescope, and twenty-one by Mr. PALMER with a 6-inch Willard lens strapped to the 5-inch Floyd telescope. The Crocker telescope is provided with a 6-inch Willard lens having an equivalent focal length of 30.82 inches. The scale of the negatives obtained with this lens is therefore as follows: 1 degree = 0.538 inch; or, 1 inch = 1.86 degrees. The lens used by Mr. PALMER has an equivalent focal length of 25.99 inches, making the scale of his negatives as follows: 1 degree = 0.454 inch; or, 1 inch = 2.20 degrees. The reproductions all have the same scale as the original negatives.

Unfortunately, owing to the close proximity of the comet to the Sun at first, and later to the pressure of other work, it was impossible to obtain a series of exposures of uniform length. Two exposures were made with each instrument on the first night to determine if possible any evidences of rapid changes in the struc-

ture of the tail. These showed the comet to be too faint to give anything satisfactory with a short exposure; therefore, the entire available time on subsequent nights was devoted to a single one. Later, when two long exposures could have been obtained, the comet had receded from the Sun, and consequently rapid changes would not be likely to occur. The exposures varied in length from half an hour to three hours and a half, most of them being from one to two hours in length.

The length of the tail was apparently greatest about May 10th. The photographs show it to have been more than nine degrees. Taking into account the distance of the comet from the Earth, and the angle between the tail and the line of sight, the tail must have been more than 15,000,000 miles long. At that time the comet was visible to the naked eye as a hazy star between the fourth and fifth magnitudes. According to the ephemeris by MÖLLER (*Astronomische Nachrichten*, No. 3556) the comet did not reach its second maximum of brightness until May 22d; yet by May 15th the tail had shortened to $5^{\circ} 40'$ with an exposure of $2^h 24^m$. Owing to the uncertainties produced by different conditions of the sky and various lengths of the exposure times, the changes in the length of the tail are perhaps less interesting than the changes in its shape.

The greatest change of which we have evidence took place between the exposure made on May 6th and that of May 7th. These negatives are too weak for reproduction, the exposures being each less than one hour in length. Upon the one of May 6th (exposure 30 minutes) the tail consists of one main branch, 7 degrees in length, with a short streamer on each side. Upon the negative of May 7th (exposure 55 minutes) there is quite a number of streamers on either side of the main branch, which is not so long as on the previous night, and the entire comet has the appearance which would be produced by the head rotating about an axis through the comet and Sun, giving to the tail a twisted aspect. It has this same general appearance on the photograph (here reproduced) of May 8th, but the twist seems to extend further from the head than on the previous night. Slight traces of this appearance are still to be seen on the photograph of May 9th. During all this time, with the exception of May 6th, the main portion of the tail extended in a straight line from the comet, but upon the date above mentioned there is a sharp bend in the tail at about three degrees from the head.



(1) May 18, 1899. $13^{\text{h}} 42^{\text{m}}$ to $15^{\text{h}} 28^{\text{m}}$.

(2) May 19, 1899. $13^{\text{h}} 51^{\text{m}}$ to $15^{\text{h}} 26^{\text{m}}$.

(3) June 5, 1899. $11^{\text{h}} 41^{\text{m}}$ to $15^{\text{h}} 12^{\text{m}}$.

COMET *a* 1899 (SWIFT).

(Photographed by H. K. PALMER.)

Turning to the reproduction of May 18th, we see that the tail was then slender and decidedly curved. On the following night it was more curved, and presented the peculiar appearance of having been split down the middle and one half taken off, leaving a sharp line along the concave side of the tail. The photograph of June 5th shows a short, stubby tail with a bright streamer about half as long on each side. Most of the photographs show anywhere from one to seven streamers extending from the head or from various parts of the tail. The number of these was rarely the same on two consecutive nights, while their positions and lengths were constantly changing.

In the plate taken June 9th the nebulosity about the head of the comet had become elliptical in form and almost pronounced enough to suggest the formation of another tail at an angle of fifteen degrees from the main one. On the following night this projection had developed into two rudimentary tails. On June 13th, these still retained their position and form, while the main branch had become much fainter, but had not diminished in length. Unfortunately, the comet had then become so faint that it was almost impossible to see it behind the dark cross-wires used in guiding, and no more photographs were obtained.

At the end of nearly all the exposures made by Mr. PALMER the slide was pushed in about seven eighths of the way. The clock was then stopped, and the stars were allowed to trail on one end of the plate. By means of these trails the position-angles of what appeared to be the axis of the tail were measured. The following table gives these measures, together with the computed values of the position-angle of the radius-vector of the comet:—

POSITION-ANGLES OF THE TAIL.

Date.	Tail.	Radius-vector.	$t-r$.
May 7	275°.1	273°.0	+ 2°.1
8	271°.1	272°.7	— 1°.6
9	269°.1	272°.2	— 3°.1
10	270°.8	271°.9	— 1°.1
15	267°.1	267°.6	— 0°.5
18	260°.6	263°.0	— 2°.4
19	260°.8	260°.5	+ 0°.3
20	256°.5	258°.4	— 1°.9

This table shows the observed values, on the average, to be slightly smaller than the computed, but the difference is only a little larger than the probable error of the best measures.

The scale of these photographs is too small to show any detail

about the head. In most cases it is shown as a bright central portion four or five minutes in diameter and usually circular, surrounded by a fainter nebulous portion from ten to fifteen minutes in diameter and often elliptical. In the cases where this nebulous portion was elliptical the major axis was not always coincident or parallel with the axis of the tail.

On June 5th the negatives taken with each instrument show the nucleus as a small bright dot less than one minute in diameter. On this date there seems to have been no nebulosity about the head, although it was twelve minutes in diameter. In the reproduction it appears sharper than on other dates. Unfortunately, the nucleus has disappeared in the process of reproduction.

PHYSICAL CHANGES OBSERVED IN THE HEAD OF SWIFT'S COMET.

BY C. D. PERRINE.

After passing perihelion, SWIFT'S comet (1899 α) showed evidences of considerable internal action. Before perihelion it was simply a round mass of nebulosity, increasing in brightness towards the center, but with only a faint nucleus and little or no tail. The comet was then barely visible to the naked eye under good conditions. It again became visible in the latter part of April, after having been lost in the Sun's rays for nearly a month. It was then much changed in appearance, being much brighter and easily visible to the unaided eye. The nucleus had become much condensed and much brighter — resembling a star of $6\frac{1}{2}$ or 7th magnitude, with low magnifying powers. It also had a tail several degrees in length. It was first observed with the 36-inch refractor on the morning of May 7th, with a magnifying power of 270. The seeing was not good, the star-images being considerably blurred.

The following notes were made at the time: "No structure to be detected in the coma. The nucleus is sharp and under the atmospheric conditions existing does not differ from a star. Nucleus fully 7th magnitude, possibly brighter. North preceding the nucleus there is a small appendage brighter than the surrounding coma — about 10" in length and half as wide. The head of the comet fills the entire field (6' in diameter)."

The comet was observed again the following night, the appearance being the same.

It was next examined with the large refractor on May 11th, when a second nucleus was distinctly visible. This second nucleus was much fainter than the principal one—being estimated at 9.5 magnitude, while the principal nucleus was estimated at 8.0 magnitude. The conditions were better at the time of this observation, and it was seen that neither nucleus was quite stellar, even with low powers.

Following are the measures of position-angle and distance of the fainter nucleus referred to the brighter:—

Greenwich M. T.			Magnitudes.	
1899, May	11.99	263°.5 12".5	8.0	9.5
	12.96	261°.0 14".3	8.0	9.5
	13.98	260°.0 16".5		
	14.96	256°.6 18".2	8.0	10.0
	18.96	246°.4 25".2	9.0	11.0
	19.97	243°.4 26".5	9.5	11.0
	20.98	241°.0 29".4	9.5	11.5

The comet was again examined on May 26th, but under poor conditions, there being a nearly full moon and rather poor seeing. Following are my observing notes: "Whole comet is very much fainter. Nucleus is sharp and of 10 or 10½ magnitude. Cannot be certain of the second nucleus."

The comet was next observed on June 3d, when the nucleus was of the 9.0 magnitude and very sharp, having brightened up very much in the interval. The second nucleus was not seen, but a slight brightening in the head about 1' south of the nucleus was suspected.

On June 4th, the nucleus was stellar and of 8.5 magnitude. Surrounding the nucleus was a bright condensation similar to that of May 6th, which was elongated south. This feature was better seen with a power of 520. With the higher power, the principal nucleus resembled a disc 1" in diameter. A set of measures at 21^h 57^m, Greenwich mean time, gave 178°.0 and 23".4.

On June 6th, 7th, and 8th, this appendage was measured with the 12-inch equatorial, using a power of 150 with the following results:—

June 6.93	170°.8	12".4	10	and 12
7.91	163°.1	12".1	10½	13
8.92	155°.6	16".2	10½	13

On June 8th, the secondary condensation was very faint, and in consequence the settings are somewhat uncertain. The following measure was made with the 36-inch refractor:—

June 9.89 149°.0 16".9

On this date it was noted as "an extension of (brighter) nebulosity from the nucleus rather than a separate condensation."

On June 26th, the comet had become very faint, the entire comet not brighter than 10th magnitude. The nucleus was estimated at 12–13th magnitude.

From the above observations, it is evident that the nucleus of the comet brightened up materially prior to June 4th, when an elongation of the brighter nebulosity surrounding it took place, and that after this secondary condensation was formed the nucleus rapidly faded. It is probable that the general course was much the same in the first case of the formation of a secondary nucleus, about May 6th. I have no observations bearing on the case prior to that date; but my subsequent observations show clearly the rapid loss of light after the separation of the two nuclei. It seems reasonable to suppose that there was some physical connection between the brightening of the nucleus and the appearance of the two separate condensations.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA, July 25, 1899.

OBSERVATIONS OF SWIFT'S COMET (1899 *a*) FOR REFRACTION.

By C. D. PERRINE.

Observations were made on May 18th and June 9th with the 36-inch refractor, to detect if possible any refractive effect on the light of a star passing through the cometary matter. On each date two stars were selected in advance of the comet, so that the nucleus would pass between them. The stars were so chosen that the light from both would have to traverse the cometary matter on opposite sides of the nucleus. In this way any effect of refraction on one star would be *added* to a similar effect on the other star. The distance between the stars was measured before, during, and after the transit of the comet.

Following are the results of the measures after having been corrected for differential refraction: —

1899, May 18.—POSITION-ANGLE AND DISTANCE OF TWO STARS
OF 13.5 MAGNITUDE.

Mt. Hamilton Sidereal Time.	Angle.	Distance.
17 ^h 53 ^m 19 ^s	38° .36	....
17 58 9	....	203'' .40
18 7 53	....	203 .41
18 14 17	....	203 .45
18 25 30	38 .08	....
18 29 43	....	203 .63
19 18 39	38 .20	....
19 23 4	....	203 .37

The comet transited a line joining the stars at 18^h 8^m, at which time star *a* was 78'' and star *b* 125'' from the nucleus. The head of the comet was 174,000 miles in diameter; and hence the light of the two stars traversed cometary matter, as follows:—

Star <i>a</i>	. . .	168,000 miles
<i>b</i>	. . .	158,000

1899, June 9.— POSITION-ANGLE AND DISTANCE OF TWO STARS
OF 10TH MAGNITUDE.

Mt. Hamilton Sidereal Time.	Angle.	Distance.
17 ^h 3 ^m	178° .95	....
17 8 6 ^s	. . .	219'' .87
17 22 53		220 .07
17 37 6		220 .03
17 53 6	...	220 .03
18 50 6		220 .06

The nucleus of the comet passed between the stars at 17^h 41^m at the following distances:—

From star <i>a</i>	. . .	130'' .1
<i>b</i>	. . .	89 .9

The head of the comet was 145,000 miles in diameter. The light from the stars passed through 122,000 miles of cometary matter for star *a*, and 134,000 miles for star *b*.

At the time of the first sets of measures in each case the stars were involved in the nebosity of the comet to some extent, but the last measures were wholly free from it. The differences between the various sets of measures are small, and there is no indication in them of any systematic variation due to refraction. The dia-

grams will make clear the relative positions of comet and stars at the times of measurement. The circles represent the fields of view.

Dr. M. W. MEYER made observations at Geneva of the great comet of 1881 (1881 III), from which he deduced an appreciable refraction.*

In 1891, Professors BURNHAM and BARNARD made observations at the Lick Observatory of WOLF's comet for this purpose.†

Professor BURNHAM's measures show a slight systematic variation, but in the opposite direction from what is to be expected upon the most probable assumption of the variation of density in the comet. Professor BARNARD's observations show no systematic deviations.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA, 1899, July 28.

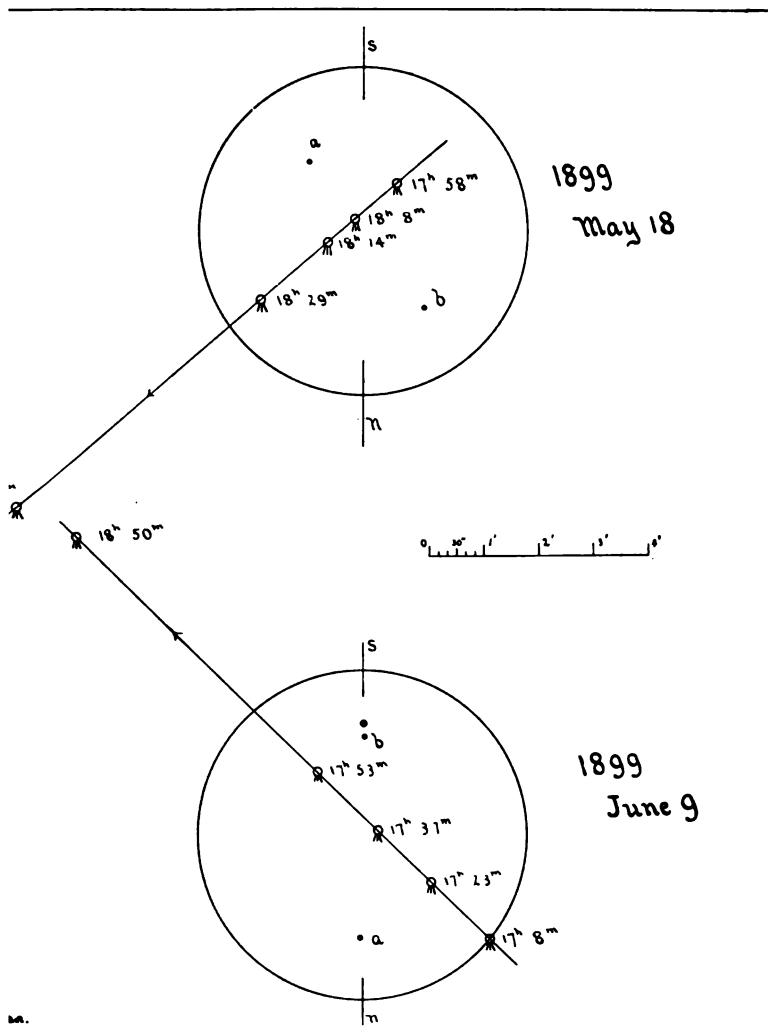
THE RADIANT POINTS OF METEORS.

By W. H. S. MONCK.

In a paper read before the Astronomical Society of the Pacific, in November, 1892, I contended that all, or almost all, meteor-radiants were of the stationary or long-enduring kind, and that the current theory which required them to shift their position in the heavens every night during the continuance of the shower entirely failed to explain the facts. "A General Catalogue of Meteor-Radiants," by Mr. DENNING, has just been published in the fifty-third volume of the "Memoirs of the Royal Astronomical Society." Mr. DENNING is probably both the greatest living observer and the greatest collector of observations of meteors, and his tables, I think, bear out the views which I expressed nearly seven years ago to the fullest extent.

Mr. DENNING reduces all radiants hitherto observed to 278 centers. But owing to the paucity of observations made in the southern hemisphere, there are perhaps thirty of these of whose persistency or otherwise we have at present no reliable information. Omitting these, it will be found that in the vast majority of cases meteors come from the same radiant for more — often for much more — than a month in succession without any perceptible variation in the radiant. Thus, taking the first twenty of Mr. DENNING's centers of radiation (which he places in order

* *Astronomische Nachrichten*, No. 2471. † *Astronomische Nachrichten*, No. 3072.



RELATIVE POSITIONS OF SWIFT'S COMET (1899 a) AND COMPARISON-STARs
USED IN OBSERVATIONS FOR REFRACTION.

of Right Ascension), one is a southern radiant of the kind already referred to, and the only other whose duration falls short of a month lasts for at least three weeks (a shower from near η Aries in October). The celebrated *Leonid* shower is one of the shortest in duration; still it continues for at least ten days without perceptible shifting, and meteors come from almost the same point from February to April, which Mr. DENNING describes as " γ *Leonids*." The question of their identity with the great meteor-shower is worthy of consideration, when we find precisely the same features presented by the *Perseid* shower of August and the *Andromede* shower of November, both of which facts are clearly signalized by Mr. DENNING, who extends the remark to all the great showers of the year, the *Quadrantids*, the *Geminids*, the *Orionids*, and even the *Lyrids* (p. 209). As to the shifting of the *Lyrid* radiant he entertains some doubt, and the only shower of which he positively affirms this property is the *Perseid* shower in July and August, of which he gives an ephemeris. There is, no doubt, much appearance of shifting in this case, yet there are circumstances which may somewhat qualify our conclusions. The earlier positions in Mr. DENNING's ephemeris agree with the somewhat diffused radiant of the α *Cassiopeids* (No. 7), which last from the beginning of July to December, and they are consequently repeated after the shifting radiant has passed on. We next get into the δ *Cassiopeids* (No. 15)—another diffused radiant including determinations at $20^\circ + 50^\circ$ and $17^\circ + 51^\circ$. Then come the θ *Perseids* (No. 30) and the χ *Perseids* (No. 32). In fact, this part of the sky is almost covered with diffused radiants; and assuming the shifting to be real, it would be no easy task to segregate the meteors belonging to this shifting radiant from those belonging to the diffused stationaries over which it was passing and to obtain any determination which was not a mixture of the two. It does not appear to be asserted that the meteors belonging to the shifting radiant can be distinguished from those belonging to the stationary radiants by any physical peculiarities, nor can it be said that the shifting radiant is sharply defined while the stationaries are diffused. The coincidence of the principal position on August 10th with a stationary radiant which is active before as well as after that date has been already noticed (No. 39). Practical observers, however, generally adopt the theory of shifting, though not agreed in the position of the radiant for any particular night. It seems pretty

plain that there is on the whole a continuous change (though not perfectly steady) in the point or area from which the maximum supply of meteors reaches us, but each point or area on the path thus taken by the maximum is active both before and afterwards. Taking up Mr. DENNING's ephemeris, it may give the point from which the largest supply of meteors will probably come on the night in question, but meteors will be found coming from that point both before and afterwards—perhaps for several months. The whole problem is a very complicated one. The August *Perseids* do not appear to exhibit the periodicity which a cometary origin would lead us to expect. The swarm seems to be greatly broken up, and its present shape is probably one which our best mathematicians would be unable to deal with, even if it were accurately known. A good explanation of the ordinary phenomena of stationary radiation—*regarded not as exceptions, but as the almost invariable rule*—is what we require, in the first instance. Having got that, we may then inquire into the cause of the anomalous features presented by the *Perseids*. I am inclined to think that Mr. DENNING might have reduced his radiants to a somewhat smaller number than 278. But the classification of radiants is a matter of considerable difficulty. When a radiant is diffused there are often sub-radiants, and the distinction between such a sub-radiant and a neighboring diffused radiant is very slight. In this way some of the radiants which are referred to one center might with equal justice be referred to another. But considerations of this kind cannot affect the general result.

ELEMENTS OF COMET 1898 VIII (CHASE).

BY ROGER SPRAGUE.

From CODDINGTON's observations at Mt. Hamilton, 1898, November 23, and 1899, January 29, and KOBOLD's observation at Strassburg, 1899, April 4, I have computed the following parabolic elements for Comet 1898 VIII (CHASE). The Mt. Hamilton observations were kindly furnished to the Students' Observatory by mail. The Strassburg observation was taken from the *Astronomische Nachrichten*, No. 3556, and used after applying a slight correction to the reduction to apparent place. In order to secure the greatest accuracy in the elements, especially

in T and ω the final values were derived by Professor LEUSCHNER's Differential Formulæ (*Beiträge zur Kometenbahnbestimmung*, pages 28-29).

ELEMENTS.

$$\begin{array}{lcl} T = \text{September } 20.073795 \text{ Gr. M. T.} \\ i = + 22^{\circ} 30' 27''.3 \\ \Omega = 95 \ 51 \ 25.2 \\ \omega = 4 \ 35 \ 31.9 \end{array} \left. \vphantom{\begin{array}{l} T \\ i \\ \Omega \\ \omega \end{array}} \right\} 1899.0$$

$$\log q = 0.358758$$

$$O - C: \Delta \lambda \cos \beta = - 1''.5; \Delta \beta = - 1''.7$$

CONSTANTS TO THE EQUATOR OF 1899.0.

$$\begin{array}{lcl} x' = [.3247374] \sin (190^{\circ} 55' 42''.00 + v) \sec^2 \frac{1}{2} v \\ y' = [.3334251] \sin (109 \ 15 \ 29.25 + v) \sec^2 \frac{1}{2} v \\ z' = [.0621375] \sin (56 \ 12 \ 13.61 + v) \sec^2 \frac{1}{2} v \end{array}$$

UNIVERSITY OF CALIFORNIA, } July 11, 1899.
STUDENTS' OBSERVATORY,

(THIRTY-SIXTH) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Dr. LEWIS SWIFT, Director of the Lowe Observatory, for his discovery of an unexpected comet on March 3, 1899.

The Committee on the Comet-Medal,

July 18, 1899. J. E. KEELER,
WM. M. PIERSON,
CHAS. BURCKHALTER.

PLANETARY PHENOMENA FOR SEPTEMBER AND
OCTOBER, 1899.

BY MALCOLM McNEILL.

SEPTEMBER.

Mercury is a morning star at the beginning of the month, rising nearly an hour and a half before sunrise. It comes to greatest west elongation on September 5th, and thereafter approaches the Sun, coming to superior conjunction on September 30th. It rises at least an hour before sunrise until the middle of the month.

Venus passes superior conjunction with the Sun on September 16th, and changes from a morning to an evening star; but as its greatest distance from the Sun during the month is only a little more than 4° , it will remain out of sight to the naked eye.

Mars is still an evening star, but is drawing nearer to the Sun, and at the end of the month it sets only a little more than an hour after sunset. It will be a very difficult object to see unless the horizon is exceptionally clear and free from haze. It moves 18° eastward and 7° southward among the stars in *Virgo*, and on September 8th is in conjunction with *Spica*, α *Virginis*, the planet being 2° north of the star.

Jupiter is also in the southwestern sky in the evening, higher up than *Mars*. It is in the constellation *Libra*, and moves 5° eastward and 2° southward; at the end of the month it is 2° west and 1° north of α *Libræ*.

Saturn is also in the southwestern quarter of the sky, in the evening higher up and nearer the meridian than *Jupiter*. It is still in the southern part of *Ophiuchus* between *Scorpio* and *Sagittarius*, and moves about 1° eastward during the month. It is about 12° east and north of *Antares*, α *Scorpii*.

Uranus is also in the same quarter of the heavens, and lies between *Saturn* and *Jupiter* in the constellation *Scorpio*, about 3° east and $1\frac{1}{2}^{\circ}$ south of the second star in the constellation, β *Scorpii*. It is, however, so low after the twilight has disappeared that it will not be easy to see it without a telescope.

Neptune rises before midnight, and is on the border of the constellations *Taurus* and *Gemini*.

OCTOBER.

Mercury is an evening star throughout the month, but does not get far enough away from the Sun for naked-eye observation. It is in close conjunction with *Venus* on October 10th, and passes *Jupiter* at a little greater distance on October 25th, but its dull light will be lost in the strong twilight.

Venus is an evening star, and increases its distance from the Sun a little during the month; so that by the end it sets a little more than half an hour after sunset. As it is at nearly its maximum distance from the Earth in miles, its brightness will be as small as possible, and it will be scarcely possible to see it without a telescope. It is in conjunction with *Jupiter* on October 29th, the nearest distance of the planets being a little more than

the Sun's apparent diameter. It also has a very close conjunction with a *Libra* on October 26th.

Mars is also in the same neighborhood a little farther from the Sun, and therefore better situated for observation; but it is now so faint that it cannot be detected in the strong twilight without a telescope. Toward the close of the month it sets an hour after sunset.

Jupiter is very close to the Sun, in conjunction with *Mars* on October 11th, with *Mercury* on October 25th, and with *Venus* on October 29th; but it sets so soon after sunset that it probably cannot be seen easily after the middle of the month.

Saturn is not far away from the others. It sets also in the early evening, but two hours later than *Jupiter*; so it will not be difficult to see it. It is still in the same neighborhood among the stars, in the southern part of *Ophiuchus* and moving toward the western part of *Sagittarius*.

Uranus is between *Saturn* and *Jupiter*, rather nearer *Saturn*. It is too faint to be seen after twilight ends, on account of the low altitude it then has.

Neptune rises in the east at about the time when *Saturn* sets.

PHASES OF THE MOON, P. S. T.

			H.	M.			H.	M.	
New Moon,	Sept. 4,		7	33	P. M.	Oct. 4,	11	14	A. M.
First Quarter,	Sept. 12,		1	49	P. M.	Oct. 11,	10	10	P. M.
Full Moon,	Sept. 19,		4	31	A. M.	Oct. 18,	2	5	P. M.
Last Quarter,	Sept. 26,		7	3	A. M.	Oct. 26,	1	40	A. M.

THE SUN.

1899.	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° '	H. M.	H. M.	H. M.
Sept. 1.	10 41	+ 8 16	5 32 A. M.	12 0 M.	6 28 P. M.
11.	11 18	+ 4 33	5 42	11 57 A. M.	6 12
21.	11 54	+ 0 41	5 51	11 53	5 55
Oct. 1.	12 30	— 3 12	6 1	11 50	5 39
11.	13 6	— 7 3	6 11	11 47	5 23
21.	13 44	— 10 44	6 22	11 45	5 8
31.	14 22	— 14 8	6 32	11 44	4 56

MERCURY.

Sept. 1.	9 35	+ 13 23	4 7 A. M.	10 53 A. M.	7 39 P. M.
11.	10 20	+ 11 48	4 19	10 59	7 39
21.	11 27	+ 5 36	5 7	11 26	5 45
Oct. 1.	12 33	— 2 9	6 2	11 55	5 48
11.	13 34	— 9 35	6 48	12 15 P. M.	5 42
21.	14 33	— 16 2	7 30	12 34	5 38
31.	15 32	— 21 6	8 9	12 54	5 39

VENUS.

Sept.	I.	10 29	+	11 2	5 9 A.M.	11 47 A.M.	6 25 P.M.
	11.	11 15	+	6 22	5 32	11 54	6 16
	21.	12 1	+	1 24	5 55	12 0 M.	6 5
Oct.	I.	12 46	—	3 41	6 18	12 6 P.M.	5 54
	11.	13 33	—	8 38	6 42	12 13	5 44
	21.	14 20	—	13 17	7 6	12 21	5 36
	31.	15 9	—	17 24	7 32	12 31	5 30

MARS.

Sept.	I.	13 3	—	6 29	8 43 A.M.	2 21 P.M.	7 59 P.M.
	11.	13 27	—	9 4	8 37	2 6	7 35
	21.	13 52	—	11 35	8 31	1 52	7 13
Oct.	I.	14 18	—	13 59	8 26	1 38	6 50
	11.	14 45	—	16 15	8 23	1 26	6 29
	21.	15 13	—	18 20	8 19	1 15	6 11
	31.	15 43	—	20 10	8 16	1 4	5 52

JUPITER.

Sept.	I.	14 17	—	12 39	10 17 A.M.	3 34 P.M.	8 51 P.M.
Oct.	I.	14 38	—	14 28	8 47	1 57	7 7
Nov.	I.	15 4	—	16 26	7 18	12 21	5 24

SATURN.

Sept.	I.	17 5	—	21 34	1 39 P.M.	6 22 P.M.	11 5 P.M.
Oct.	I.	17 10	—	21 46	11 47 A.M.	4 29	9 11
Nov.	I.	17 21	—	22 3	9 57	2 38	7 19

URANUS.

Sept.	I.	16 9	—	20 54	12 41 P.M.	5 26 P.M.	10 11 P.M.
Oct.	I.	16 12	—	21 4	10 47 A.M.	3 32	8 17
Nov.	I.	16 19	—	21 20	8 52	1 36	6 20

NEPTUNE

Sept.	I.	5 46	+	22 9	11 46 P.M.	7 5 A.M.	2 24 P.M.
Oct.	I.	5 47	+	22 8	9 49	5 8	12 27
Nov.	I.	5 46	+	22 7	7 46	3 5	10 24 A.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

		H.	M.			H.	M.
III, D,	Sept.	I.	4 22 P.M.	I, R,	Oct.	7.	5 54 P.M.
III, R,		I.	5 46	III, D,		14.	4 15
II, R,		2.	6 12	III, R,		14.	5 10
I, R,		21.	7 36				



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

NEW DOUBLE STARS.

The following double stars were found with the 12-inch equatorial of this Observatory in the course of my double-star work. As they are not contained in BURNHAM'S very complete manuscript catalogue, they may safely be called new.

The star places are all for 1900.0.

SDM. — 2° 3357.

	R. A. $11^{\text{h}} 24^{\text{m}} 16^{\text{s}}$	Decl. — $3^{\circ} 10'$		
	θ_0	ρ_0	Mags.	Seeing.
1899.440	$53^{\circ}.5$	$2''.28$	8.9 — 12.5	3 36-inch.
.451	54 .2	—	9.0 — 12.5	2 + 12
.459	53 .9	2 .07	8.5 — 13.0	3 36
1899.45	$53^{\circ}.9$	$2''.18$	8.8 — 12.7	

SDM. — 5° 3300.

	R. A. $11^{\text{h}} 24^{\text{m}} 38^{\text{s}}$	Decl. — $5^{\circ} 45'$		
1899.429	$263^{\circ}.6$	$0''.49$	9.0 — 9.0	3 12-inch.
.432	264 .7	$[0.55 \pm]_{\text{est.}}$	9.0 — 9.0	3 12
.440	255 .1	0 .51	8.9 — 9.0	2 36
.459	262 .2	0 .51	8.9 — 9.0	3 36
1899.44	$261^{\circ}.4$	$0''.50$	8.9 — 9.0.	

SDM. — 4° 3858.

	R. A. $15^{\text{h}} 13^{\text{m}} 27^{\text{s}}$	Decl. — $5^{\circ} 9'$		
	AB.			
1899.442	$351^{\circ}.6$	$0''.38$	9.0 — 9.0	3 36-inch.
.456	348 .5	0 .36	9.0 — 9.0	3 36
.459	350 .1	0 .41	9.0 — 9.0	3 36
1899.45	$350^{\circ}.1$	$0''.38$	9.0 — 9.0	

* Lick Astronomical Department of the University of California.

AB and C.

1899.442	81°.0	2".76	— 14.5	3	36-inch.
.456	79°.3	2.43	— 14.0	3	36
<u>.459</u>	<u>77°.9</u>	<u>2.44</u>	<u>— 14.5</u>	<u>3</u>	<u>36</u>
1899.45	79°.4	2".54	— 14.3		

AB and D.

1899.451	0°.7	14".99	— 12.0	3	12-inch.
<u>.454</u>	<u>0°.9</u>	<u>14.97</u>	<u>— 12.0</u>	<u>3</u>	<u>12</u>
1899.45	0°.8	14".98	— 12.0		

AB and E.

1899.456	208°.0	27".25	— 14.5	3	36-inch.
<u>.459</u>	<u>210°.0</u>	<u>27.31</u>	<u>— 14.5</u>	<u>3</u>	<u>36</u>
1899.46	209°.0	27".28	— 14.5		

The wide pair, AD, was noted with the 12-inch, and A was suspected as a very close double with the same instrument. In verifying this with the 36-inch, the faint stars C and E were found. The stars AB and C form a very pretty triple with the large telescope.

SDM.—4° 380.

R. A. 15^h 19^m 5^s. Decl. — 4° 45'

1899.459	238°.9	1".41	8.5 — 13.5	3	36-inch.
.473	239°.7	1.51	— 13.5	3	36
<u>.475</u>	<u>236°.2</u>	<u>1.37</u>	<u>— 13.5</u>	<u>3</u>	<u>36</u>
1899.47	238°.3	1".44	8.5 — 13.5		

The faint companion is barely visible with the 12-inch.

LL. 28131.

R. A. 15^h 21^m 22^s. Decl. — 5° 18'

1899.454	146°.3	0".70	8.7 — 9.1	3	12-inch.
.459	147°.1	0.67	8.5 — 9.2	3	36
<u>.473</u>	<u>148°.5</u>	<u>0.58</u>	<u>8.5 — 9.0</u>	<u>3</u>	<u>36</u>
1899.46	147°.3	0".65	8.6 — 9.1		

In the finder-field with the preceding star. Well separated with the 12-inch.

R. G. AITKEN.

July 10, 1899.

"THE SYSTEM OF *SIRIUS* ACCORDING TO THE LATEST OBSERVATIONS."

Under the above title, Mr. ZWIERS has given, in a paper printed by the Royal Academy of Sciences of Amsterdam, the results of his second investigation of the orbit of the companion of *Sirius*. In this investigation he has made use of the meridian-circle observations of the principal star, and the micrometrical observations of the companion before periastron passage, and also those made after its rediscovery by Professor AITKEN, in the latter part of 1896.

The periodic time which results from this new investigation is 48.842 years. This is a smaller value of this element than has been previously obtained by any one. AUWERS's value is the next largest, being 49.399 years. From this the values obtained by various computers range up to 58.47 years. A number of the more recent orbits give about 51 or 52 years.

According to the elements obtained by Mr. ZWIERS, the distances, as measured at Mt. Hamilton, are represented in a very satisfactory manner. It will be remembered that these distances were called in question some two years ago, it being claimed by some that they were undermeasured. This appears not to be the case. Mr. ZWIERS states that they are in accordance with KEPLER's laws, and that they fairly oscillate around the computed positions. The residuals which he has obtained, in the sense Observed - Computed, are given in the following table. In the first column are the dates of observation; in the second the residuals for the position-angles; in the third those for the distances; in the fourth the number of observations; and in the last the names of the observers:—

1896.920	— 0° 27	— 0′ .06	4	SCHAEPPERLE.
97.017	— 0 .83	+ 0 .03	8, 5	AITKEN.
206	+ 1 .84	— 0 .06	1	HUSSEY.
818	— 0 .38	+ 0 .07	4, 3	AITKEN.
839	+ 0 .34	— 0 .02	3	SCHAEPPERLE.
940	+ 1 .72	+ 0 .02	3, 2	HUSSEY.
98.151	+ 0 .63	+ 0 .18	2	AITKEN.
737	— 0 .21	+ 0 .04	3	AITKEN.
785	+ 0 .86	— 0 .02	2	HUSSEY.
99.177	— 1 .76	+ 0 .24	1	AITKEN.
286	— 0 .04	+ 0 .06	3	HUSSEY.

In like manner, the residuals obtained for the observations made at the Lowell Observatory are —

1897.802	— 1°.52	+ 0''.67	4	SEE.
828	— 1 .35	+ 0 .99	2	BOOTHROYD.
98.273	+ 0 .52	+ 0 .73	3	SEE.
276	+ 2 .37	+ 0 .79	3	BOOTHROYD

Mr. ZWIERS'S new elements are as follows: —

$$\begin{aligned}
 T &= 1894.090 \\
 \Omega &= 44^{\circ} \quad 30'.2 \\
 \pi - \Omega &= 212 \quad 6.4 \\
 i &= 46 \quad 1.9
 \end{aligned}
 \left. \vphantom{\begin{aligned} T \\ \Omega \\ \pi - \Omega \\ i \end{aligned}} \right\} 1900$$

$$\begin{aligned}
 a &= 7''.594 \\
 E &= 0.5875 \\
 \mu &= -7^{\circ}.37069 \\
 P &= 48.8421 \text{ years.}
 \end{aligned}$$

W. J. HUSSEY.

DEATH OF THE HON. T. G. PHELPS, CHAIRMAN OF THE LICK OBSERVATORY COMMITTEE.

The Hon. T. G. PHELPS, Chairman of the Lick Observatory Committee of the Board of Regents, died at his home at San Carlos on June 11th, from injuries inflicted by a recklessly-ridden bicycle.

Mr. PHELPS came of an old New England family, distinguished in the early wars of the country. He was born at Chenango, New York, December 20, 1824. In 1849, he came to this State, having been for some time engaged in the practice of law at his old home. After a short experience at the mines, he engaged in business in San Francisco, where he accumulated a competence. He took a keen interest in politics; was elected a member of the assembly, and later a State Senator. In 1875, he ran for Governor on the Republican ticket, but was defeated through a division in the party.

Mr. PHELPS was a Member of Congress from California during the Civil War, and was the trusted adviser of President LINCOLN in matters pertaining to the Pacific Coast. He was twice Collector of the Port of San Francisco. In 1880, he became a Regent of the State University, and in the absence of the Governor he presided at the meetings of the Board. When the Lick Observatory was transferred to the State by the Lick Trus-

tees, he was appointed Chairman of the Observatory Committee, a position which he held until his death. He was also Chairman of the Trustees of the new Wilmerding School.

In Mr. PHELPS'S character shrewdness and simplicity were admirably mingled. His integrity was such that it was never questioned in the heat of a political campaign. He was a man of splendid physique, and notwithstanding his wide interests in practical and public affairs, the tireless energy derived from his New England ancestry required further vent in active physical exercise. He rose at daylight, chopped his own wood, and worked in his garden or on his ranch. The great avenues of trees around his beautiful home were set out by his own hand, and he was on his way to repair a fence, about a mile from his house, when he met with the unfortunate accident which closed his honorable and useful life.

The death of Mr. PHELPS has deprived the Lick Observatory of a valued adviser, and its officers of a warm personal friend.

J. E. K.

APPOINTMENT OF FELLOWS AT THE LICK OBSERVATORY.

At a meeting of the Board of Regents of the State University, on July 11th, Messrs. E. F. CODDINGTON, R. T. CRAWFORD, and H. K. PALMER were reappointed to Fellowships at the Lick Observatory for one year, dating from August 1, 1899.

J. E. K.

GENERAL NOTES.

The Committee on Publication has decided to conduct a new department in the *Publications* under the title given above. Many notes of a general character have appeared in the Notices from the Lick Observatory, but hereafter notices in that department will be confined to accounts or results of investigations being carried on in that institution. Members and friends of the Society are invited to aid the committee in carrying out the work of this new department. Communications of general interest will be gladly received and may be sent to SIDNEY D TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Students in astronomy in the Summer School of the University of California are now (August) carrying on a telegraphic longitude campaign between the Student's Observatory, Berkeley, and the United States Coast and Geodetic Survey Observatory, Presidio, San Francisco. Thus far cloudy weather has badly interfered with the work. It is probable that in the future the Summer (?) School in astronomy will be held during the Christmas holidays, as the weather then is usually good.

Bulletin No. 10 of the Yerkes Observatory of the University of Chicago gives some measures of the fifth satellite of *Jupiter*, made by Professor BARNARD with the 40-inch telescope. A combination of these measures with those made in 1892, at the time of discovery, gives for the period of revolution $11^h 57^m 22^s.647$. Professor HALE thinks this cannot be in error more than 0^s.01.

Secretary LONG, of the Navy Department, recently appointed a Board of Visitors to examine and report upon the U. S. Naval Observatory, to consist of Senator WM. E. CHANDLER; Representative ALSTON G. DAYTON; Professor GEORGE C. COMSTOCK, Director of the Washburn Observatory; Professor GEORGE E. HALE, Director of the Yerkes Observatory; and Professor EDWARD C. PICKERING, Director of the Harvard College Observatory. This board met at the Naval Observatory on June 30th. Its report will be received with the greatest interest by astronomers all over the country.

Professor F. L. O. WADSWORTH has been appointed by the managers of the Western Pennsylvania University Director of the Allegheny Observatory, succeeding in the position Professors KEELER and LANGLEY. Professor WADSWORTH has been connected with the Yerkes Observatory since its opening, and was

previously at the Astrophysical Observatory of the Smithsonian Institution.

The following notice, concerning the Third Conference of Astronomers and Astrophysicists, has recently been issued. These conferences have proved of immense benefit to those who are able to attend. It is to be regretted that California is so far away that it is in general impossible for the Pacific Coast members of the Astronomical Society of the Pacific to attend. It is to be hoped that some time a meeting of the Conference may be held at the Lick Observatory:—

THE THIRD CONFERENCE OF ASTRONOMERS AND ASTROPHYSICISTS.

The committee charged with the selection of a time and place for holding a third conference of astronomers and astrophysicists met in the city of Washington on February 8, 1899, and by unanimous vote of the members present, Messrs. NEWCOMB, MORLEY, HALE, and COMSTOCK, resolved that such a conference should be held at the Yerkes Observatory early in the following September, the precise date to be subsequently determined by Professor HALE.

In accordance with this resolution, and at Professor HALE's invitation, the conference will be held at the Yerkes Observatory, Williams Bay, Wis., beginning on Wednesday, September 6th, and closing on Friday, September 8th.

In its plan and scope this conference will be similar to those held in 1897 and 1898 at Williams Bay and Cambridge, accounts of which have been published in this journal and elsewhere. The committee charged with perfecting a plan for the organization of a permanent society of astronomers and astrophysicists to have charge of future conferences, will report at this time.

A circular, giving information regarding local arrangements, will be issued shortly.

GEO. C. COMSTOCK, *Secretary*.

(*Astrophysical Journal*, July 1, 1899.)

Dr. T. J. J. SEE, formerly of the Lowell Observatory, and Professor MILTON UPDEGRAFF, Professor of Astronomy in the University of the State of Missouri, have recently been appointed by President MCKINLEY Professors of Mathematics in the United States Navy.

Mr. FREDERICK H. SEARES, who was for some time a member of the Publication Committee of this journal, has gone abroad to pursue the studies of astronomy and mathematics for two years in Germany and France.

The University of Michigan, at its last commencement, conferred the degree of Master of Science upon Professor W. W. CAMPBELL, of the Lick Observatory.

In view of the bequest of \$50,000 for the department of astronomy at Smith College, by the will of ELIZA HAVEN, won after long litigation, it has been decided that the department shall be known as the "Elizabeth Haven School of Astronomy." — *Science*, June 30, 1899.

FRANK SCHLESINGER, Ph. D. (Columbia), has been appointed an observer in the United States Coast and Geodetic Survey, and will be stationed at Ukiah, California, where he will take part in the international plan for the determination of the variation of latitude. — *Science*, July 7. [We hope to give an account of this plan in the next number of the *Publications*.]

In the June number of the *Astrophysical Journal*, Mr. F. R. MOULTON, of the University of Chicago, derives formulæ for the computation of a parabolic orbit from two observations of apparent position and one of the motion in the line of sight. So far as known, no computations of this nature have yet been made.

In the same number of the *Journal*, as above, Dr. ELKIN has an article, "Results of the Photographic Observations of the *Leonids*, November 14-15, 1898, at the Yale Observatory." Cameras were located at two stations, Yale Observatory and Hamden. Seven meteor trails were discussed, and an orbit derived assuming a period of 33.25 years. Only one meteor recorded itself upon the plates at both stations. Its height was found to be at appearance 59.97 miles; at disappearance, 53.14 miles.

A new variable star, B. D. $+45^{\circ}$, 3062, of the *Algol* type, was discovered some time ago at Moskow. Harvard College Observatory Circular No. 44 contains the results of an examination of all the Draper Memorial plates taken in that portion of the sky occupied by this star. The star appears on 195 plates. On 170 of these it is of full brightness, while on the other 25 it is below normal brightness. A discussion of these measures gives a period for the variable of $4^d 13^h 45^m 2^s$. It is noticeable that the variation in brightness of this star is over three magnitudes, which exceeds the variation of any other variable of the *Algol* type. The circular contains also a table of minima of this star for the balance of the year.

Nature, for June 29th, has an article by W. F. DENNING, on the Red Spot on *Jupiter*. He says: "This feature has shown a remarkable variation of motion during the last twelve months. In

the winter there was a very decided acceleration of speed, but during the past three months the motion has been again retarded. The acceleration was first noticed here on the evening of February 3d, when the marking came to the central meridian seven or eight minutes before the computed time. In the first half of 1898, and again during the last few months, the rotation period of the spot was nearly $9^h 55^m 42^s$, but for several months in the past winter the rate corresponded very nearly with $9^h 55^m 40^s.6$ Since the spot became a very prominent feature, in 1878, it has exhibited an increasing rate of rotation, the period rising from $9^h 55^m 37^s$ to $9^h 55^m 42^s$. We imagine the author meant *decreasing* rate instead of *increasing*.

A second edition of Professor CAMPBELL's book, "The Elements of Practical Astronomy," appeared some time ago from the press of The Macmillan Company. The first thing to attract the attention of a person familiar with the first edition is a decided improvement in the mechanical execution of the work. The book has been revised and enlarged. Most of the mistakes which found their way into the first edition have been corrected, and few, if any, new ones introduced. The chief additions are a chapter on the meridian-circle and a number of illustrations of instruments. A critical review of the book, by G. C. C., a well-known American astronomer, appeared in *Science* for June 16th. The criticisms and suggestions there made are well worth the serious attention of every instructor of practical astronomy. However, as G. C. C. says, the work as a whole may be cordially commended.

During the year 1898-99 the total enrollment in the courses in astronomy in the University of California was ninety-five. The total number of students enrolled was sixty-four, of whom nine were graduate students. Enrollment includes only those who completed courses.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Issues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



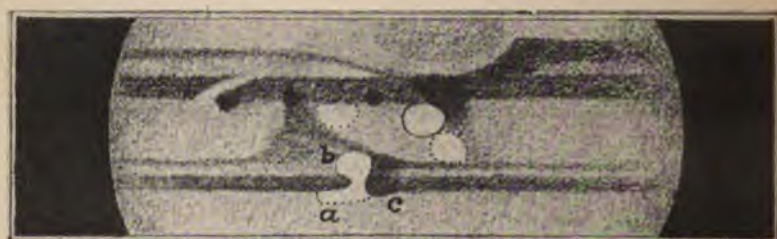


FIG. 1. 1898, March 31.



FIG. 2. April 5.



FIG. 3. April 12.

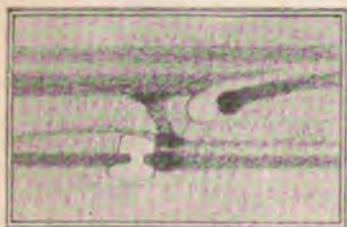


FIG. 4. May 7.



FIG. 5. May 14.

DRAWINGS OF JUPITER.
BY A. STANLEY WILLIAMS.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XI. SAN FRANCISCO, CALIFORNIA, OCTOBER 1, 1899. No. 70.

THE NORTHERN BORDER OF THE EQUATORIAL
CURRENT OF *JUPITER*.

BY A. STANLEY WILLIAMS.

It is well known that the equatorial regions of *Jupiter* are occupied by a surface current having a very high velocity compared with that of the districts immediately adjoining it on the north and south. The difference in velocity, about two hundred and fifty miles an hour, is so great, in fact, that the spots or other markings situate near the equator gain as much as five minutes on those lying just outside the current in each rotation of the planet. In other words, the equatorial spots will return to the same position on the disc, the meridian passing through the center, for instance, five minutes sooner than the extra-equatorial ones. As *Jupiter* makes two and a half of his rotations in one of our terrestrial days, the difference amounts to nearly thirteen minutes per day. The motion of an equatorial spot is so rapid that an interval of only four days is required for it to drift the length of the well-known Red Spot, the position of which is still clearly marked by the deep hollow, or bay, in the south equatorial belt opposite to it, though the spot itself is extremely faint at the present time. It is sometimes a highly interesting sight to watch day by day a conspicuous string of bright and dark spots, such as are so often to be found on the north side of the south equatorial belt, drift in solemn procession past the Red Spot.

At the present time there are some very important questions requiring investigation in connection with the borders of this equatorial current, and the complicated system of rifts, streamers, and spots characterizing these regions. The *average* boundary of the current may be said to fall nearly at the middle points of the two

great equatorial belts. Thus, referring to the accompanying sketch (Fig. 1), the average southern boundary lies in the bright rift separating the components of the double south equatorial belt; and the average northern boundary falls about the middle of the north equatorial belt, which at the date of the sketch was single, though it likewise is generally double. Outside these limits the surface markings rotate at a rate not differing very greatly from that of the Red Spot. Inside, all markings belong to and move with the swift equatorial current. The line of demarcation is usually very sharp, without much indication of any transition stage between the currents, the velocities of which, as already mentioned, differ by about two hundred and fifty miles an hour. Hence it is not surprising to find various important and complex changes occurring in and about the borders of the equatorial current.

The *average* boundaries of the current are as indicated above, but actually considerable variations occur in their positions from time to time. This is particularly the case with regard to the northern limit. In 1887 and the succeeding five or six years, the northern boundary fell at, or, at any rate, very close to, the extreme south edge of the north equatorial belt. In other words, this prominent dark belt was then situate *outside* of the equatorial current altogether. At most, only a narrow strip at its extreme southern edge was included in the current. Last year, however, a very remarkable change had occurred, resulting in the whole of the north equatorial belt being included *within* the equatorial current, which indeed actually extended a little north of that belt. This change is indeed so very remarkable, that it seems desirable to place on record without delay the evidence by which it is established.

My observations of *Jupiter* last year commenced on February 27th. On that night I noticed a white spot on the north side of the north equatorial belt, and it was noted as being in mid-transit across the disc at $12^h 37^m.5$. No particular attention was attracted by the spot at the time, as similar spots have nearly always been very common in this locality, and it was at the time considered, like these, to rotate at a rate not differing greatly from that of the Red Spot.

But on March 20th a rather peculiar group of spots was observed, consisting of a white spot on the north side of the belt, connected by means of a bright rift *through* the belt, with a white

spot on the south side of the latter. Immediately following was a dark double spot. The appearance presented by the two white spots connected by the bright rift through the belt was very striking, and on the first available occasion the region was re-examined, in order to see what, if any, changes had taken place. This occasion presented itself on March 29th, when the configuration seemed unaltered, and on March 31st the sketch (Fig. 1) was made. It will be seen that the appearance still remained practically the same as it had been on March 20th and March 29th, so that the whole group evidently rotated at one and the same rate; this rate, moreover, being that of the equatorial current. The group of spots was observed on many occasions in the course of the next three months, during which period its appearance remained substantially unaltered, as will be seen by the accompanying sketches. At my last observation, on June 1st, the aspect of the group was still unchanged. It was also found on subsequent investigation that the white spot which I had observed on the north side of the belt on February 27th was identical with that marked *a* in Figure 1, though at the time neither the white spot *b* nor the connecting rift were noticed, probably owing to the indifferent seeing prevailing then. The dark spot *c* had, however, been observed.

In the following tables I have brought together the observed times when the three spots, *a*, *b*, and *c*, of Figure 1, were in mid-transit across the disc. In some cases the double-spot *c* may have been observed as one object, whilst in others the time may relate to the transit of a single component; but the two spots were situate so nearly north and south that any differences arising from this would be very slight. Column 3 contains the corresponding longitudes of the spots according to *System I* of Mr. CROMMELIN's "Ephemeris for Physical Observations of *Jupiter*," published in the *Monthly Notices*.* The fourth column gives the residuals according to the rotation periods stated below, which periods appear to represent satisfactorily the observations of the different spots. In the last column, D.=W. F. DENNING, Bristol; M.=H. MACEWEN, Glasgow; P.=T. E. R. PHILLIPS, Yeovil, Somerset; W.=A. S. WILLIAMS. The times are all Greenwich mean times.

* The rotation period of *System I* is 9^h 50^m 30^s.

WHITE SPOT *a.*

		Transit.	Longitude.	O—C	Observer.
		h. m.	°	m.	
1899.					
Feb.	27	12 37.5	128.0	— 4.2	W.
Mar.	20	10 31.3	129.8	+ 2.2	"
	29	10 56.7	127.5	0.0	"
	31	12 9.3	127.8	+ 0.8	"
Apr.	5	10 16.8	129.3	+ 4.0	"
	12	9 29.5	126.4	+ 0.5	"
	16	11 52	125.2	— 0.9	"
	21	9 58.3	125.7	+ 0.7	"
	23	11 6.6	123.3	— 2.9	"
May	7	9 41	122.0	— 2.8	"
	16	10 16	124.1	+ 2.2	"

WHITE SPOT *b.*

Mar.	20	10 31.3	129.8	— 1.4	W.
	29	10 59.7	129.4	— 0.5	"
	31	12 12.3	129.7	+ 0.4	"
Apr.	5	10 14	127.6	— 2.1	P.
	"	10 14.3	127.8	— 1.8	W.
	12	9 32	128.0	— 0.3	P.
	"	9 35.5	130.1	+ 3.2	W.
	16	11 55	127.1	— 0.9	"
	21	10 0.3	127.0	— 0.2	"
	23	11 9.7	125.2	— 2.8	"
	30	10 35.8	130.1	+ 6.5	"
May	7	9 43	123.2	— 3.4	"
	9	10 57.8	124.6	— 0.9	"
	14	9 1	122.1	— 3.1	P.
	"	9 10.2±	128.3±	(+ 6.1)	W.
	16	10 17	124.8	+ 0.7	"
	"	10 20	126.6	+ 3.7	P.
	21	8 27.5	127.3	+ 5.8	"
June	1	10 5	122.8	+ 0.4	W.
	22	7 58	118.6	— 2.5	D.

DARK SPOT *c.*

Feb.	27	12 59.5	141.4	+ 0.6	W.
Mar.	20	10 46.3	138.9	— 1.5	"
	29	11 15.7	139.2	— 0.4	"
	31	12 32.3	141.9	+ 4.3	"
Apr.	5	10 34.8	140.3	+ 2.1	"
	12	9 51.5	139.8	+ 1.9	"
	16	12 9	135.6	— 4.6	"
	17	7 53	137.5	— 1.4	D.
	21	10 18.3	137.9	— 0.3	W.

1898.	Transit.		Longitude.	O—C	Observer.
	h.	m.	o	m.	
Apr. 23	11	29.8	137.4	— 0.9	W.
30	10	47.8	137.4	— 0.4	"
May 7	10	3.5	135.8	— 2.5	"
9	11	13.3	134.0	— 5.1	"
14	9	24.7	137.1	+ 0.4	"
"	9	25	137.3	+ 0.7	P.
16	10	36.5	136.7	— 0.2	W.
"	10	41	139.4	+ 4.3	P.
"	10	41	139.4	+ 4.3	M.
21	8	42.5	136.5	— 0.1	P.
June 15	9	5	135.0	+ 0.2	"
22	8	23	133.9	— 1.4	"

The approximate rotation periods of the three spots are:—

Spot $a=9^h 50^m 26^s.0$ (190 rotations)

" $b=9 50 25.5$ (229 ")

" $c=9 50 27.8$ (280 ")

the mean period of the group being $9^h 50^m 26^s.4$.

The presence of the white spot a on the north side of the north equatorial belt shows clearly that in 1898 the equatorial current extended north of the belt, but the actual boundary was only a small distance to the north of the northern edge of the belt. This is indicated by the presence of a number of dark spots just north of the belt, which spots rotated at a rate not differing very greatly from that of the Red Spot. Two of them are shown in Figure 2, the most preceding of the two appearing again in Figure 3.* It will be seen that on April 5th the group of spots a, b, c was just following the last-mentioned spot, but on April 12th it preceded the latter by a long interval. I was in hopes of catching the white spot a when in the act of drifting past one of these dark spots, but bad weather always interfered at the critical time.

The permanency of aspect of the group of spots is rather remarkable, since it appears that little or no change of importance occurred during an interval of more than three months, either in its appearance or rate of motion. During this period considerable changes of aspect and some curious shifts in position occurred in some of the spots on the north side of the

* The spots are represented as isolated, but they actually were situated on a fine belt in good seeing, appearing like beads strung on a thread. The mean rotation period of the three plainest spots was $9h 55m 26s.3$, according to Mr. W. F. DENNING.

south equatorial belt shown in the accompanying sketches, but the disturbances producing these do not seem to have extended to the group of spots about the north equatorial belt.

This permanency of aspect is significant. The north equatorial belt is occasionally the seat of most abnormal and intense disturbance. These occasions of abnormal disturbance seem to arise when the northern boundary of the equatorial current falls on or within the belt. By reason of the two conflicting currents, the dark material of the belt is then literally torn to shreds, resulting in innumerable spots, streaks, and detached fragments, which undergo rapid changes. This state of things occurred in 1896-97, and again during the late opposition (1899). The belt appears to be in a comparatively quiescent state if it is situated either wholly without the equatorial current, as in 1887 and the succeeding five or six years; or within it, as was the case in 1898. Not but what there are always very many spots and other details visible about the belt, but the changes which then take place are comparatively slow and inconsiderable.

The rapid drift of the equatorial spots past the Red Spot alluded to above is illustrated by the present sketches. Figure 1 shows the group of spots on the north equatorial belt under the preceding end of the Red Spot, and in Figure 5 the group appears again in nearly the same relative position. But in the interval between March 31st and May 14th the group of spots has made very nearly a complete circuit of the planet relative to the Red Spot.

This rapid drift of the equatorial spots ought to be well known by now, but it is nevertheless only too common to find even observers of considerable experience still endeavoring to identify spots near the equator from their position relative to the Red Spot, or in the system of longitudes representing approximately the motion of the latter (*System II* of Mr. CROMMELIN's ephemeris).

HOVE, SUSSEX (Eng.), 7th September, 1899.

PHOTOGRAPHIC OBSERVATIONS OF THE RING
NEBULÆ IN *LYRA* AND *CYGNUS*.

BY JAMES E. KEELER.

Of the four annular nebulae known to the HERSCHELs, only two are visible—or easily visible—in northern latitudes. One of these is the Ring nebula in *Lyra*, familiar to all observers with small telescopes. The other, in *Cygnus*, is small and faint, and hence has been very little studied. Many of the planetary nebulae are bounded by bright rings, or contain bright rings within an outer and fainter limit; but for various reasons these nebulae are usually placed in a separate class.

In connection with a series of researches on the nebulae, now in progress with the Crossley reflector, the two ring nebulae above mentioned were photographed a number of times during the past summer. In what follows I give briefly the substance of a paper which was read before the conference of astronomers at the Yerkes Observatory, in September.

The Ring Nebula in Lyra.—Several very good drawings have been made of this nebula, the best of which, in my opinion, is one made by Professor HOLDEN with the 26-inch refractor of the U. S. Naval Observatory. The original is in the library at Mt. Hamilton. All the drawings agree in showing an elliptical ring, fainter near each end of the major axis, and filled with faint nebulosity. This nebula has also been successfully photographed by many observers. In some respects, the photographs which have been obtained are superior to the eye observations. Thus, a small star exactly in the center of the ellipse is easily photographed with even a small instrument. Visually, however, it is very faint. It is not shown in the drawings of Lord ROSSE and LASSELL, and it escaped TROUVELOT with the Harvard 18-inch and HOLDEN with the Washington 26-inch refractor. There is, I believe, much reason to suppose that this star is variable, though it has remained practically constant in brightness for a good many years. Its magnitude is 15.4, according to an estimate by Professor BURNHAM, in 1891.

But the Ring nebula is not such an object as the photographic telescope, in its usual forms, is capable of dealing with most successfully. In reflecting telescopes the focal length is generally

short, and hence the image of the nebula is very small; in photographic refractors the actinic power of the nebula's light is greatly weakened by the absorption of the glass lenses. The most suitable instrument for photographing the Ring nebula would be a large reflector of unusually great focal length.

The Crossley reflector has a focal length of 17 feet 6 inches, and the diameter of the nebula on the photographic plate is about 2^{mm} , or 0.08 inch. If the focal length were, say four times greater, the image would still be bright enough to photograph with a reasonably short exposure, and the pictures of the nebula would doubtless far surpass any ever made.

A great deal of detail is however visible in an image 2^{mm} in diameter, while the brightness of the nebula makes the exposure times very short. The following list of negatives made with the Crossley telescope under very fine conditions shows the photographic efficiency of the instrument very clearly:—

1899.

- July 13. Exposure 2 hours. All parts of the nebula greatly over-exposed.
- July 12. Exposure 1 hour. Over-exposed.
- July 14. Exposure 30 minutes. Good photograph; treated for over-exposure.
- July 14. Exposure 10 minutes. Best general picture of the nebula.
- July 14. Exposure 2 minutes. Distinct image.
- July 14. Exposure 1 minute. Faint image.
- July 14. Exposure 30 seconds. Barely visible image.

With refracting telescopes exposures of nine, ten, and even twenty-four hours have been given to the Ring nebula. Such excessive exposures would be useless with the Crossley telescope, as they would merely produce a great black blotch on the plate.

From the best of the negatives in the above list, positives were made on glass with an enlargement of about eleven diameters. These positives, requiring no magnifier for their examination, were more convenient for many purposes than the original negatives.

The most interesting discovery resulting from an examination of the photographs is that the Ring nebula is made up of a number of narrower rings interlacing somewhat irregularly, the spaces between the component rings being filled with fainter nebulosity. One of these rings forms the preceding end of the main ring. Sweeping around to the north end of the minor axis, it becomes

very bright, perhaps by superposition on the broader main ring of the nebula at this place. It crosses this ring obliquely, forming the brightest part of the whole nebula, and then forms the inner boundary of the main ellipse toward its following end. Another of the narrow rings forms the inner boundary of the ellipse on the north side; it crosses the main ring obliquely, and on the south projects beyond the elliptical outline of the nebula, converting it into an oval whose more pointed end is toward the east.

There are other, but irregular and much fainter, projections of nebulosity beyond the general outline of the nebula, at a number of places on the ring, particularly at the two ends. The position-angles and amount of projection have been measured for all these nebulous masses, but it is unnecessary to give the results here.

The nebulosity within the ring, which appears in ordinary telescopes like a faint uniform veil, has a very interesting structure on the photographs. Lord ROSSE's drawing in the *Philosophical Transactions* for 1844 shows the interior space of the nebula crossed by a series of dark and bright bands in the direction of the major axis, and this drawing has, I think, generally been regarded as fanciful. Nevertheless, the structure it represents is confirmed by the Crossley photographs — and confirmed, so far as I am aware, for the first time. There are, however, only three dark and two bright bands within the ellipse. One of the dark bands is centrally placed. The direction of the bands is not exactly that of the major axis of the main ellipse, but in a position-angle about 5° greater.

The details described above are not visible, or can at most be only suspected, with the 36-inch refractor, notwithstanding the brightness, large size, and fine definition of the nebula as seen with this instrument. The advantage of the photograph in this case lies in its exaggeration of differences of brightness which are too small to affect the eye in visual observation.

Besides the central nucleus, the photographs show only one star within the darker inner space. It is just visible at times with the 36-inch refractor, and its magnitude cannot be far from 16. There is also a star discovered by Dr. HOLDEN at the preceding extremity of the major axis. Other stars which have been seen in the ring by various observers seem to be bright patches caused by the interlacing of the component rings.

In 1893, Professor BARNARD* discovered a small nebula, near

* *Astronomische Nachrichten*, No. 3200.

the Ring nebula in *Lyra*, with the 36 inch refractor. The Crossley photographs show that it is a left-handed, two-branched spiral, with an extreme diameter of about 30".

The Ring Nebula in Cygnus (G. C. 4565).—This is a nearly circular nebula, only about half the size of the one in *Lyra*, and very much fainter. There is a drawing by Sir JOHN HERSCHEL in the *Philosophical Transactions* (1833),* in which the nebula is represented as a faint ring without detail, and one by Lord ROSSE,† in which the faint nebulosity within the ring is also shown. I do not know of any other published drawings or of any photographs whatever.

Two photographs of this nebula were made with the Crossley reflector in August of the present year, and from one of them, to which an exposure of two hours was given, enlargements were made in the manner already described.

As shown on the photographs, the nebula is a nearly circular ring, measuring 42".5 by 40".5. The outer boundary is fairly sharp. On the inside of the ring the brightness fades somewhat gradually toward the center, which is marked by a nucleus, or star, of about the sixteenth magnitude. At several places, narrow streaks of nebulosity project from the inner edge of the ring, part way to the center, like imperfect spokes. One bright star (14.5 mag.) is shown on the ring. It was observed by Lord ROSSE. There is no evidence that this star is physically connected with the nebula, and its position on the ring is probably an accidental effect of projection. The nebula is surrounded by small stars, the distances and directions of which from the central nucleus have been measured on the photographs, in order that any proper motion of the nebula may be detected by repeating these observations at some time in the future.

THE RISE AND PROGRESS OF ASTRONOMY IN CENTRAL EUROPE.—III.

BY SIDNEY D. TOWNLEY.

Although without a rival as a practical astronomer, still TYCHO BRAHE was not without contemporaries. The science of astronomy was being advanced by a few persons in Germany, chief

* Plate XIII, fig. 48. † Observations of Nebulae and Clusters of Stars, Plate V.

among whom may be mentioned WILLIAM IV, Landgrave of Hesse (1532 to 1592).

Even before TYCHO he perceived that astronomy needed above all accurate observations. His observatory, in Cassel, was a tower on the Zwehrer Thor. The tower was surmounted by a revolving dome; and this was, as far as known, the first time this now generally adopted device was used. Observations were made by the Landgrave from 1516 to 1567; but in the latter year the government of the province fell upon him, and but little observing could be done thereafter.

Later, ROTHMANN, a mathematician, and BUERGI, an expert clockmaker, were engaged by the Landgrave to carry on the observing. Through a pupil of TYCHO's they learned of the improvements made in the instruments at Uraniborg, and immediately adopted many of them. Clocks were extensively used by these observers, and in that practice their methods differed materially from TYCHO's. Their observations were made chiefly upon the fixed stars, the intention being to form a catalogue of over a thousand stars. The work, however, was never completed, as it was soon given up after the death of the Landgrave, in 1592. BUERGI was a very ingenious person, and is said to have used logarithms and applied the pendulum to regulate the running of a clock. Neither of these discoveries, however, was given to the world.

Many students came to TYCHO to act as his assistants, but of these one only achieved fame. JOHN KEPLER (1571 to 1630) was born at Weil, in Wurtemberg. Reared in poverty, he was nevertheless able, being a born scholar, to obtain a university education. He attended the University of Tuebingen, and it was while a student there that he obtained his first knowledge of astronomy, through the teaching of MOESTLIN, professor of mathematics. KEPLER'S studies, however, were mostly along the line of metaphysics and theology, and it was therefore with reluctance that he accepted a lectureship in mathematics at Gratz in 1594.

Being of a very imaginative and speculative turn of mind, one of the first questions that troubled KEPLER was concerning the causes of the number, size, and motion of the planets. He attempted first to establish a relation between the distances of the planets from the Sun. After working along many lines, he happened to remember that there were only five regular solids, and

these he thought might be connected in some way with the five spaces between the six planets then known. He finally evolved the following: the orbit of the Earth was represented by a sphere; about this a dodecahedron was circumscribed; and around that another sphere, which gave the orbit of *Mars*; around that a tetrahedron was placed, the corners of which mark the sphere of the orbit of *Jupiter*; around that sphere again a cube was placed which roughly gave the orbit of *Saturn*. In the inside of the sphere of the earth an icosahedron was inscribed, and inside the sphere of that an octahedron, and the spheres of these two represented the orbits of *Venus* and *Mercury*.

The result of these labors, together with an account of all the unsuccessful attempts, was published by KEPLER in a work called *Mysterium Cosmographicum*. I mention it not from the intrinsic value of the work, but because a copy of it was sent to TYCHO BRAHE, who recognized the genius of the author and wrote a letter to KEPLER, thus beginning the acquaintance which in after years led to results of such momentous importance to the science of astronomy.

TYCHO gave KEPLER this sound advice: "To lay a solid foundation for his views by actual observation, and then, ascending from these, to strive to reach the causes of things."

In 1601, KEPLER was made Imperial Mathematician by the Emperor RUDOLPH II, on condition that he should assist TYCHO BRAHE in Prague. It was TYCHO's intention to construct tables of the Sun, Moon, and planets, founded on his own observations. His end came, however, before the work was fairly commenced, and on his deathbed he intrusted the task to KEPLER, with the request that the tables be called after their benefactor, RUDOLPH. Upon the death of the master, the assistants, with the exception of KEPLER, soon went away. KEPLER was appointed to TYCHO's position, and the great mass of observations accumulated by that brilliant observer fell into KEPLER's hands. They could not have fallen into worthier ones. Every one knows the three famous laws brought forth from them. As long as the science of astronomy shall exist they will stand as an imperishable monument to the genius of JOHN KEPLER.

It is not my purpose to enter into the details of the labors by which KEPLER arrived at these results. They were derived from investigations of the motion of the planet *Mars*, this planet being chosen on account of the large eccentricity of its orbit and the

large number of observations which TYCHO had made upon it. His method was to suppose some theory of motion, then to calculate the positions of *Mars* according to this theory, and see if the positions agreed with TYCHO's observed places. For a long time he held to the idea of circular motion. Hundreds of different suppositions were tried, and each thrown aside when it was found not to agree with TYCHO's observations. As logarithms were not then invented, we can easily imagine the tremendous labor necessary to carry out these calculations. Years were spent in this work; and we hardly know which to admire more—the genius to think out the theories, or the patience to carry out the calculations.

After years of labor, he finally gave up the idea of uniform circular motion. That seems to us an easy thing to do; but we must remember that at that time scholars' minds were still enslaved by the philosophy of ARISTOTLE, and according to that philosophy circular motion was the only perfect motion, as it would be impossible for the planets to move in any other way. KEPLER thought first to try a variable circular motion, and to facilitate the computations divided the orbit into sectors, and the second law was almost immediately found, namely, that the radius-vector describes equal areas in equal times. This result aroused great enthusiasm in him; but comparison with TYCHO's observations soon showed that it was not sufficient. KEPLER announced this in the following quaint way: "While thus triumphing over *Mars*, and preparing for him, as for one already vanquished, tabular prisms and equated eccentric fetters, it is buzzed here and there that the victory is in vain, and that the war is raging anew as violently as before. For the enemy left at home a despised captive has burst all the chains of the equations, and broken forth from the prisms of the tables."

KEPLER'S next effort was to try an oval for the orbit. Various kinds were tried, but it then transpired that the law already found did not hold true. Finally the ellipse was tried, and KEPLER found to his great delight that when the Sun was placed at one focus the first law still held, and the places agreed with those observed by TYCHO BRAHE within the unavoidable errors of observation. Hence the result: the orbit of *Mars* is an ellipse with the Sun at one focus. The complicated system of epicycle, equant, deferent, eccentric, and so forth, was swept away forever.

The first two laws were published in 1609, in his greatest work, *Astronomia nova de motibus stellæ Martis ex-observationibus Tychoonis Brahe*, generally designated by the title, "Commentaries on the Motions of Mars." Still KEPLER was not satisfied, but kept thinking over the idea that he had long held, that there must be some connection between the distances of the planets and the times of their revolution. After several years of thinking and calculating, the third law was finally evolved, namely, the squares of the times of revolution of the planets about the Sun are proportional to cubes of their mean distances from the Sun. This law was published in 1619, in a work called *Harmonices Mundi* (Harmonies of the World).

Other important works were issued by KEPLER, chief among which may be mentioned *Epitome Astronomiæ Copernicanæ*, in 1621, and *Tabulæ Rudolphinæ*, in 1627. He prefaced the tables with a fanciful home of astronomy, which is here reproduced from FRISCH's edition of KEPLER's works (Vol. VI).

Thus in brief is an outline of the life and work of JOHN KEPLER. Although he held the high-sounding title of Imperial Mathematician, yet his salary consisted chiefly of promises, so that nearly his whole life was spent in extreme poverty. When we consider this fact, and also the fact that the man was afflicted with much illness and domestic trouble, we cannot look upon the stupendous labor performed and the brilliant results reached as anything short of marvelous. KEPLER was possessed of a most brilliant imagination and gave it full rein, but finally always tested a theory by comparing the results of it with TYCHO's observations. These were held infallible, and any theory that did not agree with them was promptly abandoned, no matter how many years of trial it had cost.

One might suppose that a nature like KEPLER's would be particularly open to the ideas and methods of astrology; but he is said to have entertained the greatest disgust for everything astrological in character. Still for many years, when it was impossible to get his salary paid, he published and sold an almanac in which were given weather predictions and astrological prognostications. Notwithstanding the many disappointments of his life, due to poverty, illness, and domestic troubles, he obtained great intellectual pleasure from his discoveries, as is witnessed by the following lines, written after the discovery of his third law: "What I prophesied two-and-twenty years ago, as

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KEPLER'S "HOME OF ASTRONOMY."

soon as I discovered the five solids among the heavenly orbits,—which I firmly believed long before I had seen PTOLEMY'S *Harmonies*,—what I promised my friends in the title of this book, which I named before I was sure of my discovery,—what, sixteen years ago, I urged as a thing to be sought,—that for which I joined TYCHO BRAHE, for which I settled in Prague, for which I have devoted the best part of my life to astronomical contemplations,—at length I have brought to light, and recognized its truth beyond my most sanguine expectations. It is not eighteen months since I got the first glimpse of light, three months since the dawn, very few days since the unveiled Sun, most admirable to gaze upon, burst upon me. Nothing holds me; I will indulge my sacred fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far away from the confines of Egypt. If you forgive me, I rejoice; if you are angry, I can bear it; the die is cast, the book is written, to be read either now or by posterity, I care not which; it may well wait a century for a reader, as God has waited six thousand years for an observer."

While KEPLER was thus engaged in clearing away the rubbish that filled the solar system, an invention which was destined to exert a great influence on the progress of astronomy was placed before the world. The invention of the telescope marked a new departure in the methods of the practical astronomer. It is scarcely possible to overestimate the value of this invention. The telescope has become an indispensable part of nearly every astronomical instrument. All honor is therefore due the man who first gave the invention to the world, and who first employed the telescope as an instrument of astronomical research.

"It is a remarkable circumstance in the history of science, that astronomy should have been cultivated at the same time by three such distinguished men as TYCHO, KEPLER, and GALILEO. While TYCHO, in the fifty-fourth year of his age, was observing the heavens at Prague, KEPLER, only thirty years old, was applying his wild genius to the determination of the orbit of *Mars*, and GALILEO, at the age of thirty-six, was about to direct the telescope to the unexplored regions of space. The diversity of gifts which Providence assigned to these three philosophers was no less remarkable. TYCHO was destined to lay the foundation of modern astronomy by a vast series of accurate observations made with the largest and the finest instruments; it was the

proud lot of KEPLER to deduce the laws of the planetary orbits from the observations of his predecessors; while GALILEO enjoyed the more dazzling honor of discovering by the telescope new celestial bodies and new systems of worlds."*

GALILEO GALILEI (1564 to 1642) was born in Pisa. He early displayed rare qualities as a student and a fondness for experimentation. In the University of Pisa his fondness for mathematics asserted itself, and he soon deserted the study of medicine, which had been chosen for him by his father. At the age of twenty-six he was appointed to a professorship in mathematics in Pisa. After a short time he changed to a similar position in Padua, which was held for many years.

Although greatly interested in astronomy, especially the Copernican system, still his greatest work was in the line of mechanics. Here was an unbroken field—there was nothing to guide him. He was a pioneer in this direction. He created science out of chaos, and established the laws of motion which a few years later led to the celebrated discoveries of NEWTON. Important as this work of GALILEO'S was, in its relation to the determination of the actual motions of the heavenly bodies, still it is not my purpose to deal with it, but rather with his pioneer work with the telescope, which means so much to the progress of practical and observational astronomy.

Still of this it is perhaps hardly necessary to write in any detail, for the story is familiar to every student of astronomy. It was in 1609 that GALILEO first heard of the invention, by a Dutch optician, of an instrument which made distant objects look near. He immediately set to work to reproduce the instrument, and soon accomplished the result by using a convexo-plane spectacle lens for an object-glass and a concavo-plane spectacle lens for an eye-piece. This magnified three times, and gave erect images, like opera-glasses of the present time; while the telescopes made by the Dutch opticians were of two convex lenses, and consequently gave inverted images. Soon afterwards an instrument that magnified ten times was made, and a little later one that gave a thirty-fold magnification. With this GALILEO examined the heavens, and a host of new things were at once revealed,—the mountains of the Moon, phases of *Venus* (as COPERNICUS had predicted), satellites of *Jupiter*, nebulae, countless stars of the Milky Way, rings of *Saturn*, and spots on the Sun. These

* BREWSTER: "Martyrs of Science," p. 187.

indeed were great discoveries, and they added many arguments to the support of the Copernican theory, which was by no means as yet universally adopted. The telescopic discoveries of GALILEO were announced, in a history of astronomy, published in 1747 by GEORGE COSTARD, in the following quaint way:—

G A L I L E O,

who was the first that applied a Telescope to the Heavens, where he discovered the spots in the Sun, the four Satellites of *Jupiter* (called by him the *Medicean Stars*, in honour of the dukes of *Tuscany*) and *Saturn* to be of a very strange and uncouth figure.

This last arose from the imperfection of Telescopes at that time, and the vast distance of *Saturn* from the *Sun*, or *Earth*. . . .

Galileo observed unevennesses in the Moon, like hills and vallies; and that the *Milky Way*, and *Nebulæ*, observed in some parts of the Heavens, as in the head of *Orion*, in *Cancer*, &c. are nothing more than a congeries of Stars, too small to be seen by the naked eye.

That the Moon is inhabited, and hath in it hills and vallies, is said to have been the opinion of *Anaxagoras*, about the year before Christ 480, as we saw before.

But this could only be matter of conjecture, before the invention of Telescopes, or, perhaps, was asserted by him, as a consequence of his other opinion, that the Sun and Moon were material; an opinion that had like to have cost him his life. . . .

Galileo observed, by means of his Telescope, that *Venus* did appear sometimes horned like the Moon; and thereby verified the conjecture of *Copernicus*, and so far proved that his was the true System of the World.

The first object examined by GALILEO with a telescope was the Moon, and we reproduce on the next page his drawing of that object, together with one of sun-spots.* He published his telescopic discoveries in a little book under the title, *Nuncius Sidereus* (or the Sidereal Messenger).

These discoveries also gave GALILEO some new arguments against the Aristotelian philosophy, and in that way contributed perhaps more to the progress of learning than in any other. We must not forget that the tenets of the Aristotelian philosophy were

* These are copied from ARTHUR BERRY'S new work, "A Short History of Astronomy."

still held to tenaciously, and persistently and fervently taught in all the universities. No one dared doubt the statements of that ancient sage, and it would have been philosophic heresy to test

these long-established truths by simple experiments. GALILEO, however, was the exception to the rule, and some of his earliest experiments showed the falsity of some of the teachings of ARISTOTLE. Every one is familiar with his famous experiment of dropping two iron balls of different weights from the leaning tower of Pisa to demonstrate that the velocity with which a body descended did not depend upon its weight.



GALILEO'S DRAWING OF THE MOON.

GALILEO's criticism and ridicule of the Aristotelian philosophy led him into many bitter controversies and made many enemies among his colleagues. Although a devout Christian, yet his espousal of the Copernican system eventually brought him into disfavor before the Church. In 1616, he was enjoined from teaching the obnoxious system; but in 1632, upon the publication of his famous "Dialogue on the Two Chief Systems of the World, the Ptolemaic and Copernican," the churchmen were thoroughly aroused, and GALILEO was summoned to appear before the Inquisition at Rome. It is not my purpose to review the details of the dreadful ordeal through



SUN-SPOTS — BY GALILEO.

which this martyr of science was obliged to pass. He sought only the truth. He was right, and his enemies were wrong, and he knew it as well as we do. To save himself from terrible torture and probable death at the stake, the old man at last recanted, declared the Copernican system to be false, and that the Earth did not move.

It has been stated, and quite generally believed, that GALILEO after recanting arose from his knees and said to a friend, "It does move, though." There is no probability whatever that he did say this, as is pointed out admirably by LODGE, in "Pioneers of Science": "Those who believe the story about his muttering to a friend, as he arose from his knees, '*E pur si muove*,' do not realize the scene. 1st, there was no friend in the place; 2d, it would have been fatally dangerous to mutter anything before such an assemblage; 3d, he was by this time an utterly broken and disgraced old man; wishful, of all things, to get away and hide himself and his miseries from the public gaze; probably with his senses deadened and stupefied by the mental sufferings he had undergone, and no longer able to think or care about anything, — except perhaps his daughter, — certainly not about any motion of this wretched earth."

We may now leave this poor old man. The balance of his life was spent in forced seclusion. Continual illness, grief, and finally blindness were added to his burdens. His enemies were triumphant. He fell, but the truths which he defended and then denied lived on. GALILEO'S contributions to astronomy were brilliant, but his contributions to mechanics were in many respects more remarkable. As before stated, he was a pioneer in this field, having inherited from his predecessors nothing but erroneous traditions and obscure ideas. His work in this line alone was sufficient to insure for him a high place among the scientific men of all ages.

"The scientific character of GALILEO, and his method of investigating truth, demand our warmest admiration. The number and ingenuity of his inventions, the brilliant discoveries which he made in the heavens, and the depth and beauty of his researches respecting the laws of motion, have gained him the admiration of every succeeding age, and have placed him next to NEWTON in the lists of original and inventive genius. To this high rank he was doubtless elevated by the inductive processes which he followed in all his inquiries. Under the sure guidance

of observation and experiment, he advanced to general laws; and if BACON had never lived, the student of nature would have found in the writings and labors of GALILEO, not only the boasted principles of the inductive philosophy, but also their practical application to the highest efforts of invention and discovery." *

(To be continued.)

ELEMENTS AND EPHEMERIS OF COMET *c*, 1899) (GIACOBINI).†

By MISS A. HOBE, Y. KUNO, S. C. PHIPPS, AND ROGER SPRAGUE.

From the first three Mt. Hamilton observations by PERRINE, kindly telegraphed to the Students' Observatory by Director KEELER, Miss HOBE, and Messrs. KUNO and PHIPPS, advanced students in the University, have computed the following elements and ephemeris of Comet *c*, 1899 (GIACOBINI):—

OBSERVATIONS.

1899 G. M. T.	^a	^δ
October 2.6758	16 ^h 32 ^m 59 ^s .7	— 4° 12' 18"
October 3.6378	16 34 22.1	— 3 53 35
October 4.6292	16 35 46.7	— 3 34 40

ELEMENTS.

$$\begin{aligned}
 T &= 1899 \text{ July } 25.31196 \text{ G. M. T.} \\
 i &= 90^{\circ} \quad 49' \quad 58'' \\
 \Omega &= 279 \quad 54 \quad 49 \\
 \omega &= 327 \quad 26 \quad 20
 \end{aligned}
 \left. \vphantom{\begin{aligned} i \\ \Omega \\ \omega \end{aligned}} \right\} 1899.0$$

$$\log g = 0.128376$$

$$O - C: \Delta \lambda \cos \beta = - 1''.5; \Delta \beta = - 0''.1$$

CONSTANTS FOR THE EQUATOR OF 1899.

$$\begin{aligned}
 x &= [9.365813_s] \sin (62^{\circ} 11' 36'' + v) \sec^{\frac{1}{2}} \frac{1}{2} v \\
 y &= [0.123290] \sin (213 \quad 33 \quad 3 + v) \sec^{\frac{1}{2}} \frac{1}{2} v \\
 z &= [0.126916] \sin (304 \quad 16 \quad 30 + v) \sec^{\frac{1}{2}} \frac{1}{2} v
 \end{aligned}$$

* BREWSTER; "Martyrs of Science."

† Communicated by the Director of Students' Observatory, University of California.

EPHEMERIS.

1899 Gr. Mean Midnight.	app. α	app. δ	log Δ	Br.
October 8 ^d .5	16 ^h 41 ^m 13 ^s .9	— 2° 24' 8"	0.3175	0.84
12 .5	46 45.2	— 1 16 5	0.3340	
16 .5	52 11.9	— 0 12 5	0.3495	
20 .5	57 34.7	+ 0 48 34	0.3640	0.60

Brightness at the time of the first Mt. Hamilton observation is taken as unity.

Mr. ROGER SPRAGUE has independently computed the orbit from the same observations which he corrected for parallax and aberration on the basis of a first approximation.

ELEMENTS BY ROGER SPRAGUE.

$$T = 1899 \text{ July } 25.5208$$

$$\left. \begin{array}{l} i = 90^{\circ} \ 38' \ 22'' \\ \Omega = 279 \ 47 \ 0 \\ \omega = 327 \ 53 \ 50 \end{array} \right\} 1899.0$$

$$\log g = 0.130868$$

$$O - C: \Delta \lambda \cos \beta = - 0''.8; \Delta \beta = + 0''.3$$

UNIVERSITY OF CALIFORNIA. STUDENTS' OBSERVATORY.

PLANETARY PHENOMENA FOR NOVEMBER AND
DECEMBER, 1899.

BY MALCOLM McNEILL.

Mercury is an evening star throughout the month, and comes to greatest eastern elongation on the morning of November 16th. During the greater part of the month it sets at least an hour after sunset, and may be seen in clear weather. It is quite near several of the planets, and there are several interesting conjunctions. It moves away from the Sun until November 16th, passing *Mars* on November 4th, morning, distance 1° 48', the Moon on November 4th, evening, with an occultation for some places, *Uranus* on November 8th, evening, distance 2° 37', and as it returns toward the Sun after November 16th, it passes *Venus* on November 26th, morning, distance 0° 43', and *Mars* again November 30th, evening, distance 0° 23'.

Venus is an evening star, increasing its distance from the Sun,

so that toward the end of the month it sets an hour after sunset, and can be easily seen. It is in conjunction with *Uranus* on November 14th, distance $0^{\circ} 24'$, with *Mars* on November 16th, morning, distance $0^{\circ} 11'$, with *Mercury* November 26th, morning, distance $0^{\circ} 43'$, and with *Saturn* November 27th, afternoon, distance $1^{\circ} 54'$.

Mars is still closer to the Sun, its distance diminishing from 20° , on November 1st, to 13° , on November 30th. At the latter date it sets only forty minutes after sunset, and is too close to be seen without a good telescope. Its conjunctions with *Mercury* and *Venus* have already been noted. It will also be in conjunction with *Uranus* on the morning of November 13th, distance $0^{\circ} 38'$.

Jupiter is very near the Sun throughout the month, and moves from a point 10° east to a point 15° west, passing conjunction on the morning of November 13th. At the end of the month, it rises a little more than an hour before sunrise.

Saturn is still an evening star, but by the end of the month it sets only an hour after sunset, and it will not be easy to see. It is in the western part of *Sagittarius*, and moves about 6° eastward during the month.

Uranus is still nearer the Sun, and passes conjunction on the morning of November 30th, becoming a morning star.

Neptune is approaching opposition with the Sun, and rises shortly after sunset.

DECEMBER.

Eclipses.—There will be an *annular eclipse of the Sun* on December 2d, visible only in south polar regions, and also a *partial eclipse of the Moon* December 16th, the beginning visible generally throughout the eastern portion of North America, Europe, Asia, and Africa, and the ending generally throughout the whole of North America, South America, Europe, and Africa. The middle of the eclipse comes at 5^h 26^m P. M., Pacific time, and it will be practically total, less than one per cent. of the Moon's diameter remaining uneclipsed.

Mercury is an evening star at the beginning of the month, but passes inferior conjunction on December 5th, and becomes a morning star. Its distance from the Sun rapidly increases, and on December 11th it rises an hour before sunrise. It reaches greatest west elongation on the morning of December 25th, and then rises nearly two hours before sunrise. It can be easily seen

in the morning twilight, on any clear morning during the latter half of the month.

Venus is an evening star, setting rather more than an hour after sunset on December 1st, and nearly two hours later on December 31st. It moves about 40° eastward during the month through *Sagittarius* into *Capricorn*.

Mars is still an evening star, but is too close to the Sun to be seen. Its distance from the Sun diminishes from 12° to 4° .

Jupiter is now a morning star, rapidly increasing its distance from the Sun. At the end of the month it rises three hours before sunrise. It moves westward 6° from *Libra* into *Scorpio*, and on December 31st it is distant from β *Scorpii* less than 1° to the west, and is moving toward that star.

Saturn is very close to the Sun, and passes conjunction on December 17th. By the end of the month it rises about an hour before sunrise, but it will not be easy to see.

Uranus is a morning star, 20° farther from the Sun than *Saturn* is; but it is too faint to be seen at the altitude it reaches before the morning twilight comes on.

Neptune is in opposition with the Sun on December 17th.

PHASES OF THE MOON, P. S. T.

		H.	M.			H.	M.
New Moon,	Nov. 3,	2	27	A.M.	Dec. 2,	4	48 P.M.
First Quarter,	Nov. 10,	5	35		Dec. 9,	1	3
Full Moon,	Nov. 17,	2	19		Dec. 16,	5	31
Last Quarter,	Nov. 24,	10	35	P.M.	Dec. 24,	7	57

THE SUN.

	R. A.	Declination.	Rises.	Transits.	Sets.
1899	H. M.	° '	H. M.	H. M.	H. M.
Nov. 1,	14 26	— 14 28	6 34 A.M.	11 44 A.M.	4 54 P.M.
11,	15 6	— 17 27	6 45	11 44	4 43
21,	15 47	— 19 57	6 57	11 46	4 35
Dec. 1,	16 30	— 21 50	7 7	11 49	4 31
11,	17 13	— 23 1	7 16	11 53	4 30
21,	17 58	— 23 27	7 23	11 58	4 33
31,	18 42	— 23 6	7 27	12 3 P.M.	4 39

MERCURY.

Nov. 1,	15 38	— 21 31	8 13 A.M.	12 56 P.M.	5 39 P.M.
11,	16 34	— 24 37	8 43	1 13	5 43
21,	17 18	— 25 24	8 51	1 17	5 43
Dec. 1,	17 15	— 23 11	7 58	12 34	5 10
11,	16 25	— 19 0	6 16	11 6 A.M.	3 59
21,	16 26	— 19 10	5 35	10 27	3 19
31,	17 10	— 21 45	5 49	10 31	3 13

VENUS.

Nov.	I.	15 14	— 17 46	7 34 A.M.	12 32 P.M.	5 30 P.M.
	II.	16 5	— 21 2	7 59	12 44	5 29
	2I.	16 58	— 23 18	8 22	12 57	5 32
Dec.	I.	17 53	— 24 26	8 42	1 12	5 42
	II.	18 48	— 24 19	8 57	1 28	5 59
	2I.	19 42	— 22 58	9 5	1 42	6 19
	3I.	20 34	— 20 28	9 9	1 56	6 43

MARS.

Nov.	I.	15 46	— 20 20	8 15 A.M.	1 3 P.M.	5 51 P.M.
	II.	16 16	— 21 51	8 13	12 54	5 35
	2I.	16 47	— 23 2	8 9	12 46	5 23
Dec.	I.	17 19	— 23 50	8 7	12 39	5 11
	II.	17 52	— 24 14	8 1	12 32	5 3
	2I.	18 26	— 24 11	7 55	12 26	4 57
	3I.	18 59	— 23 41	7 46	12 20	4 54

JUPITER.

Nov.	I.	15 4	— 16 26	7 18 A.M.	12 21 P.M.	5 24 P.M.
Dec.	I.	15 30	— 18 11	5 54	10 50 A.M.	3 46
Jan.	I.	15 57	— 19 37	4 24	9 15	2 6

SATURN.

Nov.	I.	17 21	— 22 3	9 57 A.M.	2 38 P.M.	7 19 P.M.
Dec.	I.	17 35	— 22 17	8 14	12 54	5 34
Jan.	I.	17 50	— 22 26	6 29	11 8	3 47

URANUS.

Nov.	I.	16 19	— 21 20	8 52 A.M.	1 36 P.M.	6 20 P.M.
Dec.	I.	16 26	— 21 38	7 3	11 46 A.M.	4 29
Jan.	I.	16 34	— 21 55	5 1	9 52	2 33

NEPTUNE.

Nov.	I.	5 46	+ 22 7	7 46 P.M.	3 5 A.M.	10 24 A.M.
Dec.	I.	5 43	+ 22 5	5 45	1 4	8 23
Jan.	I.	5 39	+ 22 4	3 36	10 55 P.M.	6 14

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

	H.	M.
III, D, Dec. 18.	4	1 A.M.
III, R,	18.	5 28
I, R,	19.	5 17

Jupiter is too near the Sun for observation of eclipses until the middle of December.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

ON THE VARIABLE VELOCITY OF *POLARIS* IN THE LINE OF SIGHT.

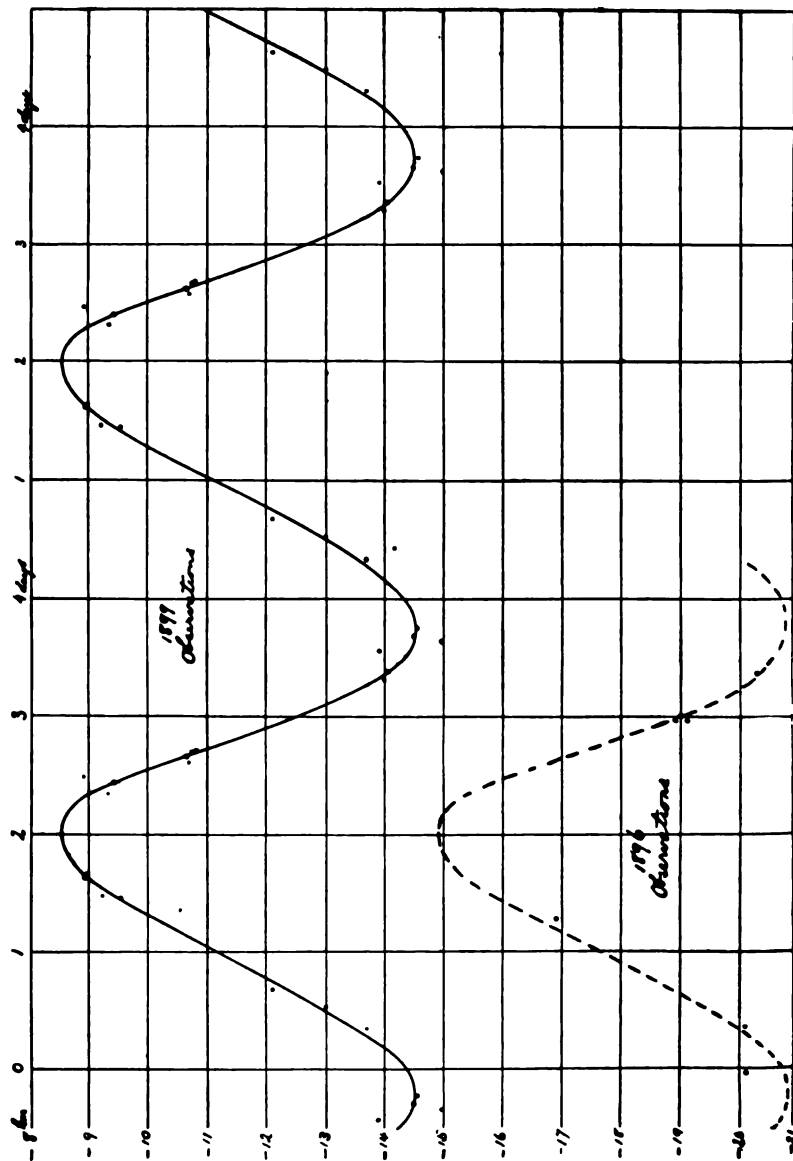
Six measures of the velocity of *Polaris* in the line of sight were secured at the Lick Observatory in 1896, as follows:—

1896, Sept. 8,	— 20.1 ^{km} per second.
“ 15,	— 19.1
“ 23,	— 18.9
Oct. 5,	— 19.0
Nov. 11,	— 20.1
Dec. 8,	— 20.3

The negative sign is used to indicate approach toward the Solar System. These results, extending over a period of three months, are in such excellent agreement that the velocity of this star was not suspected to be variable. The extreme range of 1.4^{km} is no larger than would be expected from the unavoidable errors of observation. The velocity of the star was assumed to be — 19.6^{km}, the mean of the six separate results.

Following my custom of securing frequent checks on the current results of observation, by remeasuring the velocity of *Venus*, *Mars*, or some of the brighter stars, an additional spectrogram of *Polaris* was obtained on 1899, August 8th. Measurement of the plate gave a velocity of — 13.0^{km}, or an apparent change since 1896 of 6.6^{km}. In order to test the matter further, on August 9th, spectrograms of *Polaris* and of β and γ *Andromedæ* were secured. That of *Polaris* gave a result of — 10.6^{km}, whereas those of β and γ *Andromedæ* reproduced the values obtained for these stars in previous years. Additional plates of *Polaris*, on August 14th and 15th, gave results of — 8.9 and — 14.9^{km}, leaving no doubt that the star was a binary of comparatively short period,

* Lick-Astronomical Department of the University of California.



VELOCITY-CURVE FOR OBSERVATIONS OF POLARIS IN THE LINE OF SIGHT.

the investigations were continued. Following are the velocities observed in 1899, up to date:—

Greenwich mean time.			Velocity.	Measures by
1899, Aug.	9 ^d 0 ^h 46 ^m		— 13.0 ^{km}	CAMPBELL.
	9 20 5		— 11.2	"
	9 20 5*		— 11.1	"
	9 20 5†		— 10.1	WRIGHT.
	14 22 45		— 8.9	CAMPBELL.
	16 0 8		— 13.9	"
	23 0 19		— 10.7	"
	24 0 49		— 15.1	"
	24 0 49†		— 14.8	WRIGHT.
	26 0 55		— 9.4	CAMPBELL.
	26 0 55†		— 8.5	WRIGHT.
	27 0 18		— 10.6	CAMPBELL.
	27 16 12		— 14.0	"
	28 0 47		— 14.7	"
	28 0 47†		— 14.3	WRIGHT.
	28 16 19		— 13.7	"
	29 0 25		— 12.1	"
	29 18 49		— 9.6	"
	29 23 57		— 8.9	"
	30 16 10		— 9.3	"
Sept.	4 16 11		— 14.1	"
	6 18 6		— 9.2	CAMPBELL.
	11 16 13		— 9.4	"
	11 22 29		— 10.7	WRIGHT.
	11 23 5		— 11.0	CAMPBELL.
	12 23 33		— 14.6	"

plotting these velocities with reference to the times of observation, it was found that the velocity varied from about $8\frac{1}{2}$ km/sec, and back to $8\frac{1}{2}$ in a little less than four days. Assuming the epoch of $3^d 23^h 15^m$, which may be slightly in error, the observations are charted as black dots in the upper portion of the accompanying illustration, in the space lying between 0 and 4

They are repeated, in order to reproduce the cycle, in the space between 4 days and 4 days. The smooth curve, drawn as far as possible through the charted points, is the velocity-curve

remeasurement of the same plate, which is the poorest one in the 1899 series.
 measures of the same plates by Mr. WRIGHT.

of the bright *Polaris* in its revolution around the center of gravity of itself and an invisible companion. Some slight doubt exists as to the form of the curve in the regions below 1, 2, 3, 4, etc., since these portions correspond to our daytime, when observations could not be secured. In the course of a few revolutions these portions will correspond to night-time, and observations to locate them will be obtained.

A preliminary computation shows that the orbit of *Polaris* around the center of gravity is nearly circular, the eccentricity of its ellipse being about 0.15. The major semi-axis of the ellipse, multiplied by the cosine of the angle which the plane of the orbit makes with the line of sight, is about 160,000^{km}; or less than half the distance between the Earth and Moon. While we may never know the angle of inclination, we are justified in saying that the orbit of *Polaris* around the center of gravity is probably comparable in size with the orbit of the Moon around the Earth. Just as the center of gravity of the Earth and Moon lies within the Earth's surface, so is it probable that the center of gravity of *Polaris* and its close companion falls inside of the bright *Polaris*. The velocity of this center of gravity with reference to the Solar System is at present about -11.7^{km} per second.

The point of greatest interest brought out by the observations is that the results obtained in 1896 lie far outside the present range of velocities. A little of the discrepancy might be due to a revolution of the line of apsides of the elliptical orbit, described above; but I think the greater part of it must be due to a change in the velocity of the center of gravity of the binary system, produced by the attraction of a third body.

It happened that the six plates of 1896, referred to above, were secured at intervals differing less than half a day from multiples of the period of the binary system. They would, therefore, show but little change in velocity. Very recently, while taking the observational data for the plate of 1896, November 11th, out of my note-book, I chanced to see, on a neighboring page, the record of another plate of *Polaris* obtained on 1899, November 12th, accompanied by the note that it was a defective plate, given to a San Francisco astronomer. The plate was at once written for, and received. It is a very poor plate, but measurable. It gave a velocity of -16.9^{km} .

Charting the 1896 observations with reference to the assumed period, $3^{\text{d}} 23^{\text{h}} 15^{\text{m}}$, they fall as shown in the lower portion of the

illustration. They are well represented by the dotted curve, which is of the same form as the curve for 1899, immediately above it.

If the forms of the velocity-curves of the binary system are the same for 1896 and 1899, the present velocity of the center of gravity of the binary system differs about $6\frac{1}{2}^{\text{km}}$ from its value in 1896.

The observations were made with the Mills spectrograph attached to the 36-inch telescope.

W. W. CAMPBELL.

1899, September 30.

PHOTOGRAPHIC EFFICIENCY OF THE CROSSLEY REFLECTOR.

The reflecting telescope has been so little used in this country, since the time of HENRY DRAPER, that a few notes on the photographic efficiency of the Crossley reflector may be of interest to American readers.

The Crossley dome is built on the farther end of a long rocky spur, which extends from the principal summit of Mt. Hamilton toward the south, and is within a few minutes' walk (or climb) of the main Observatory. The mirror, which has a very fine figure, has an aperture of three feet, and a focal length of seventeen feet six inches. The mounting, as compared with the beautifully mounted large refractors of the Observatory, is undoubtedly a rude piece of mechanism, but with sufficient experience of its numerous idiosyncrasies, the observer can obtain negatives with exposures of four hours' duration, with only an occasional failure.

At present the Crossley telescope is being used for photographic observations of nebulae. For such work the summer months at Mt. Hamilton present almost ideal conditions. The sky is continuously and often brilliantly clear, while the dryness and purity of the air are such that the silvered surfaces retain their brilliancy without any care on the part of the observer. Within the last week, however, the smoke from forest fires (from which there seems to be no escape in even the remotest corners of the earth) has greatly dulled the brightness of the sky, and has interfered most annoyingly with the photographic work. In the winter months, on the other hand, the conditions are generally bad, on account of storms, snow, fog, or dampness; yet there are many nights, between the spells of bad weather, on which the telescope can be used.

To one who, like myself, has always worked with refracting telescopes, the photographic power of a large reflector is surprising. In this respect, the Crossley reflector does not, of course, surpass any other reflecting telescope of like dimensions, but its photographic "rapidity" is certainly very considerably greater than that of a refracting telescope of the same angular aperture. This is due to the fact that the silvered surfaces absorb less of the chemically active light than the glass lenses of a refractor, and it is noteworthy that this superiority of the reflector becomes more pronounced the finer the atmospheric conditions under which the two classes of instruments are compared. On one of the fine nights which I have mentioned, when the Milky Way shines with astonishing splendor and the whole heavens look phosphorescent, the photographic activity of the reflector is remarkably increased. But the performance of the refractor is not greatly changed, for the reason that the short light-waves, which are transmitted more abundantly by the unusually clear air, are in any case strongly absorbed by glass.

To illustrate the photographic rapidity of the Crossley telescope, I give the following examples of exposure-times in which well-known nebulae have been photographed:—

The Ring nebula in *Lyra* has been photographed on several occasions, and the results are described in another part of the present number of the *Publications*. It will be seen that the best general representation of the nebula was obtained with an exposure of ten minutes. On this plate the stars are perfectly round and very small. The disc of the central star of the nebula has a diameter of $3''.5$; that of the smallest stars shown does not exceed $1''.5$. On the same plate is a double star (not resolved) the equal components of which are about $2''$ apart, while their magnitude is not less than 17 or 18. It will hardly be observed visually. The central star, which has a visual magnitude of 15.4, according to BURNHAM, gave a distinct image in one minute.

Photographs of small planetary nebulae have been made, not only for the purpose of ascertaining the exposure-times required for such objects, but to see what amount of detail can be shown in a surface of such small dimensions. With regard to the latter purpose, it was found that a large amount of detail was shown, but that visual observation with the 36-inch refractor was more satisfactory than photographic observations with the reflector.

In the case of the small but remarkable planetary nebula G. C. 4628 ($26'' \times 16''$), the best general picture was obtained in two minutes, while the "ansæ," extending outward from and connected with the main nebula, were well shown in ten minutes.

Another planetary nebula which has been photographed is G. C. 4964. Eight images were obtained on the same plate by slightly changing the position of the plate-holder between the exposures, which ranged from two minutes to one second. The images which received exposures of one minute, thirty seconds, and twenty seconds respectively, were the best. A weak image, in which the central star was just visible, was produced in two seconds, and a bare trace of the nebula was visible at the place where the exposure was one second.

The planetary nebula in *Draco*, G. C. 4373, has also been photographed, with quite similar results; and the small nebula discovered by Professor BARNARD near the star *Merope* is distinctly shown on a negative of the *Pleiades* which was exposed for thirty seconds.

The photographic power of the reflector which is illustrated in the foregoing examples is very advantageous in the case of objects which are of very unequal brightness, as a very full light-action, and consequently softening of contrasts, is obtained with a comparatively short exposure. If, for instance, a plate is exposed for ten minutes to such an object as the great cluster in *Hercules*, and rather strongly developed, a negative is obtained which shows very distinctly all the brighter stars. If the plate is exposed for two hours, and is then very lightly developed, the brighter stars appear much as before, but the swarms of minute stars, to which a globular cluster seems to owe its nebulous aspect, also appear on the plate, so that the photograph closely represents the appearance of the cluster as seen in a large telescope. On a photograph of the cluster in *Hercules*, made with the Crossley reflector on July 13th, with an exposure of two hours, over 5,400 stars were counted within the limits of the cluster. The average diameter of a star disc is $3''.5$. A discussion of the distribution of stars in the cluster, as shown by this photograph, has been made by Mr. PALMER.

With exposures of four hours, stars and nebulae are photographed which are far beyond the range of the 36-inch refractor. On one plate ($3\frac{1}{4} \times 4\frac{1}{4}$ in.) sixteen new nebulae were found. It would be easy with this instrument greatly to

increase the number of known nebulae; but the discovery of new nebulae, all of which would necessarily be faint, seems to be much less important than the gain of further information about nebulae already known. For this reason no search has been made for new objects, though a catalogue will be made in due time of those which have been found in the course of other investigations.

J. E. K.

COMET NOTES.

Since its rediscovery by Mr. PERRINE on the morning of June 11th,* HOLMES'S Comet has been regularly observed here, but, so far as is known at present, it has not been seen elsewhere. The rediscovery position enabled Mr. ZWIERS to correct his search ephemeris very satisfactorily. Five observations secured by the writer between August 11th and September 9th give average residuals of only $+0^{\circ}.66$ in R. A. and $+9''.2$ in Decl. (O. — C.) to the revised ephemeris.

The comet on the last-named date was still very faint, not as bright as a fourteenth-magnitude star, and showed only a slight central condensation, no true nucleus. Unless it exhibits some of the unexpected light changes that made its former apparition so remarkable, it is likely to remain beyond the reach of all but the most powerful telescopes.

Comet Tempel II has also been observed regularly here since its rediscovery on May 6th of the present year. At first very faint, it became bright enough to be an easy object in a small telescope in the latter part of July. It is now losing light rapidly; but on the night of September 26th it was still readily visible in the $3\frac{1}{2}$ -inch finder of the 12-inch telescope, being about as bright as a tenth-magnitude star. The nucleus, though now quite faint, — about thirteenth-magnitude — is still clearly marked. The comet reached its greatest southern Declination about the 11th of September, and is now moving north and east. It will, therefore, remain in good position for observation for some months to come.

R. G. AITKEN.

September 27, 1899.

NOTE ON THE SEEING AT MT. HAMILTON.

While in the East, during the present summer, I met several astronomers who referred to the good seeing at Mt. Hamilton, as

* See these *Publications*, No. 68, p. 134.

if it were essentially dependent upon the ocean fogs coming in at a lower altitude than the Observatory and by covering the surrounding country so as to keep down the radiation from the valleys and cañons about us, producing that equality of atmospheric conditions which accompanies good seeing.

My experience is somewhat at variance with this idea. The presence of fogs over the valleys does not appear to be a very important factor in the case. The seeing is sometimes good and sometimes bad when the fog is present, and it is sometimes good and sometimes bad when it is absent. On some of the finest nights that I have known there has been no fog in sight. The conditions which give rise to our good seeing must be sought in other causes, probably in the prevailing meteorological characteristics of this region.

W. J. HUSSEY.

COMET 1898 VII (CODDINGTON).

This comet has now been under observation at the Lick Observatory from June 11, 1898, to September 7, 1899, or about fifteen months. During this period it has described a heliocentric arc of more than 150 degrees. At the time of the last observation it was approximately 4.46 astronomical units, or 412,000,000 miles from the Sun. It was also about the same distance from the Earth. Its brightness was estimated at fifteenth magnitude.

E. F. CODDINGTON.

GENERAL NOTES.

The Committee on Publication has decided to conduct a new department in the *Publications* under the title given above. Many notes of a general character have appeared in the Notices from the Lick Observatory, but hereafter notices in that department will be confined to accounts or results of investigations being carried on in that institution. Members and friends of the Society are invited to aid the committee in carrying out the work of this new department. Communications of general interest will be gladly received and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Dr. HENRY S. PRITCHETT, Superintendent of the United States Coast and Geodetic Survey, recently spent several weeks upon the Pacific Coast, looking after the affairs of the Department. A portion of his time was spent at Ukiah, California, superintending the erection of a latitude observatory to co-operate in the international campaign to determine the variation of the latitude. The Department proposes also to locate a magnetic observatory in California, which will co-operate with similar observatories to be established near Washington, D. C., and in the Hawaiian Islands, and with the magnetic observatories already established at Toronto, Havana, Mexico, and Manila. About ten years will be necessary to obtain a complete magnetic survey of the United States and its possessions. The Lick Observatory and the Students' Observatory, Berkeley, were among the places inspected by Dr. PRITCHETT for the location of the magnetic observatory, but we understand that his decision has not yet been announced.

The *Astronomical Journal*, No. 467, is given up to an article, by Professor S. J. BROWN, of the United States Naval Observatory, in which a new determination of the orbits of the satellites of *Mars* is made from a discussion of observations made with the 26-inch equatorial of the Naval Observatory and the 36-inch equatorial of the Lick Observatory, 1894-96.

Since we mentioned in the last number of the *Publications* a criticism of the second edition of CAMPBELL'S "Elements of Practical Astronomy," it is perhaps only just to state that *Science* for September 8th publishes a reply by Professor CAMPBELL. Of the reply we can say, as we did of the review, "The criticisms and suggestions there made are well worth the serious attention of every instructor of practical astronomy."

Miss LAURA SHEARER, a student of the University of the Pacific, College Park, has taken the "Definitive Orbit of Comet 1898 VI," as her thesis for the degree of B. S.

A new catalogue from the Zeiss Optical Works, Jena, gives two new combinations of lenses by which the secondary spectrum is almost entirely eliminated. One, the binary apochromatic lens, has a ratio of aperture to focal length of 1:17 to 1:20, while the other, the triple apochromatic lens, one flint and two crown glasses, has a ratio of 1:10 to 1:15.

The report of the Royal Observatory, Cape of Good Hope, for 1898, contains details of the mounting of the McLean telescope, a 24-inch photographic and 18-inch visual combination. The visual lens has proved entirely satisfactory, but some alterations are necessary in the photographic lens. The lenses were made by Sir HOWARD GRUBB. A new transit-circle is also being constructed for the observatory by TROUGHTON & SIMMS. It is to be mounted within a house of sheet steel.

A new determination of the photometric magnitudes of the stars of the *Pleiades* has been made by MUELLER & KEMPF, at the Potsdam Observatory. Their results are contained in Nos. 3587-88 of the *Astronomische Nachrichten*.

The last number of the *Vierteljahrsschrift der Astronomischen Gesellschaft* contains accounts of the work done, in 1898, at the various observatories and other astronomical institutions of Central Europe and also at the observatories at Cambridge (U. S. A.), Cordoba, and Williams Bay. We give below an outline of the chief lines of work carried out in the three institutions last named. We hope in the next number to be able to give a similar outline for the European institutions:—

CAMBRIDGE, OBSERVATORY OF HARVARD COLLEGE.—The researches of former years were carried on under the direction of Professor E. C. PICKERING. The work was almost entirely photometric and photographic in nature.

1. Photometric: The 15-inch and 6-inch equatorials were used in the observation of variable stars. The meridian photometer observations of all the stars, down to and including the 7.5 magnitude, were completed down to -40° declination. The instrument has now been sent to the branch station in Arequipa, Peru, where the work will be continued to the south pole. Photometer observations have been commenced on certain regions where stars from 7.5 to 13 magnitude are observed.

2. Photographic: The various photographic telescopes were employed in work upon the *Algol* stars at minimum, *Jupiter's* satellites in eclipse, occultations, clusters, spectra of fainter stars, trails of stars near the pole to determine constants of aberration, nutation, and precession, etc., etc.

About 7,000 photographs are taken each year. These are measured and worked up by Mrs. FLEMING and twelve women assistants.

The work done in Cambridge is being extended to the southern skies at the station in Arequipa. The principal instrument there is the 24-inch Bruce telescope, with which the sky is being charted and the spectra of fainter stars observed. On one plate images of 400,000 stars appeared.

"A line of eight meteorological stations is maintained, extending from the sea-level to the top of El Misti, and on the other side into the valley of the Amazon. The elevations of these stations are: 100, 4,150, 8,060, 13,300, 15,600, 19,200, 11,000, and 3,000 feet respectively. Self-registering instruments record continuously the temperature, pressure, wind, etc."

"About fifty observers take part in the scientific work of the observatory, and its income of about \$50,000 is derived from funds given by private individuals for this purpose. It receives no aid from the State, nor from the general funds of the University."

CORDOBA.—The work so admirably planned and carried out for fifteen years by Dr. GOULD has been greatly retarded during several years past by the financial difficulties in which the Argentine Republic is involved.

Dr. THOME gives the following programme of work for 1898:—

1. Extension of the southern *Durchmusterung* (visual).
2. A. G. Zones: Reobservation upon the meridian-circle of all the stars in the Cordoba *Durchmusterung* catalogues as bright as 9.2 magnitude; and, besides, such fainter ones as are given in our meridian catalogues.
3. Observations of comets, planets, and casual phenomena.
4. Determination of the geographical co-ordinates of the principal cities and towns of the Republic.
5. Computations corresponding to the above.
6. Computation of the ephemerides of the fifty-four stars in the Cordoba circumpolar list, for each year.
7. Preparation of the star-maps to accompany the *Durchmusterung* catalogues.
8. Time service: Signals every day at 11 A. M.
9. Various observations made at the solicitation of astronomers.
10. Revision and publication of the results.

In writing of the observation of meteors, Dr. THOME makes the following interesting statements concerning the weather: "The change which has taken place in our climate since the '80's is very remarkable. From being one of the finest in the world for astronomical pursuits, it has fallen to an average of little more than one clear night in two, and the extraordinary transparency of the atmosphere no longer exists. The annual average of clear nights in the interval from 1873 to 1881 was 269; from 1890 to 1898, it was 195; which, with the greater frequency of interruptions by clouds, implies a loss of nearly three months of observing yearly over the former period. In the year 1879, there was a period of ninety nights of uninterrupted meridian work. The change must be attributed, in part at least, to the creation of the large artificial lake in a

valley of the mountains, about twelve miles distant, and to the irrigated zone now extending to the north and south of the city in our immediate vicinity."

WILLIAMS BAY — YERKES OBSERVATORY.—After giving a brief historical account of the observatory, Director HALE mentions briefly the scientific investigations which are being carried forward. The following extracts may be of interest:—

"*Double Stars.*—Professor BURNHAM has employed the 40-inch telescope on two nights of the week in the measurement of double stars, with the special purpose of preparing a catalogue of his own stars for publication. He has hitherto measured about one thousand pairs. No attempt has been made to search for new double stars, although a few have been discovered in the course of the work."

"*Star-Clusters.*—Professor BARNARD has verified with the 40-inch telescope a number of the variable stars discovered by Professor PICKERING in the cluster *Messier 5*. He has determined the period of several of these stars, and his results agree well with those of the Harvard observers. Two or three variables not marked on the Harvard photographs have been noticed in the observations. Professor BARNARD is also engaged in triangulating several star-clusters, and has measured the relative positions of 115 stars in *Messier 5*, 30 in *Messier 3*, and 50 in *Messier 13*. The latter positions agree well with those obtained photographically by Professor SCHEINER. In some instances, three stars have been seen and measured where but one is shown on SCHEINER's photographs. It has been found that the stars designated by SCHEINER with the numbers 393, 401, 749, and particularly 382 (his normal star), are much fainter visually than photographically."

"*Planets and Satellites.*—During the summer of 1898 Professor BARNARD made a series of forty-three measures of the diameter of *Venus* and eleven of the diameter of *Mercury* with the 40-inch telescope. No traces of the linear markings recently described by several observers could be detected, although the atmospheric conditions were frequently excellent and the vague markings seen by Professor BARNARD at Mt. Hamilton were visible."

"*Spectra of Stars of Secchi's Fourth Type.*—A photographic study of stars of SECCHI's fourth type was undertaken by the writer [Professor HALE], in conjunction with Mr. ELLERMAN, in January, 1898. A large number of photographs have been secured of stars ranging in magnitude from 5.4 to 8.2. The earlier work was done with a single prism, but later it was found possible to use a dispersion of three prisms, even with the faintest stars. Several hundred lines have been measured in these spectra and the radial velocity has been sufficiently well determined to permit the wave-lengths to be corrected for motion. The photographs, which have been made here with the 40-inch telescope and by Professors KEELER, CAMPBELL, and DURIER, have led to the conclusion that the spectra of these stars contain bright lines. Photographs recently obtained, which are much superior to the earlier ones, show an almost perfect agreement of the spectrum of *132 Schjellerup* with that of the third type star μ *Geminorum* in certain regions in the

blue and green. There can thus be no doubt of an intimate connection between stars of the third and fourth types. It has also been found possible to arrange the spectra of eleven stars of the fourth type in a series having at one end *280 Schjellerup* and at the other end *155 b Schjellerup*. In *280 Schjellerup* the characteristic dark bands (attributed to carbon) are inconspicuous, while in *155 b Schjellerup* they are strongly developed." A detailed account of this work is given in the August number of the *Astrophysical Journal*. It is the first of a proposed series on the same subject.

Other important investigations are being carried out, the natures of which are indicated in the following headings given by Professor HALE: Stellar Photography; *Leonid* meteors; Spectrum of the Chromosphere; Solar Photography; Determination of Stellar Velocities in the Line of Sight; Miscellaneous Stellar Spectroscopic Work; Spectra of *Jupiter* and *Saturn*; Color Curve of the 40-inch Objective; Theory of Optical Instruments; Stellar Heat Radiation; Variable Stars; Experiments in Lunar Photography with the 40-inch Telescope; and Spectrum of the Iron Spark in Air.

At the annual meeting of the American Association for the advancement of science, held in Columbus, Ohio, August 21st to 26th, Professor ASAPH HALL, Jr., Director of the Observatory of the University of Michigan, was elected vice-president of Section A, Mathematics and Astronomy. Three papers of astronomical interest were read before the meeting,—one by ASAPH HALL, Jr., one by R. W. MCFARLAND, and a third by H. C. LORD. An abstract of Professor LORD's paper—"Some Points in Spectroscope Design"—written by himself, is given below:—

This paper supplemented one published in the *Astrophysical Journal* for April, with twelve photographs of the solar spectrum, and discussed them by curves drawn in accordance with the method above given. The photographs were taken with cameras whose focal lengths were in the ratio 1:3:4, and with an optical dispersive power of one light flint prism, one dense flint prism, two dense flint prisms, and the third order of a 14,000-line grating, combining each camera with each prism or grating in turn. These photographs showed that of the three factors, namely, optical contrasting power, optical resolving power, and photographic resolving power, that optical contrasting power was by far the most important. That full photographic resolution would be secured on rapid plates when the width of the diffraction pattern of a line at λ 4340, whose width was 0.168 Angstrom units, was in the neighborhood of 0^{mm}.08 and when this width was as small as 0^{mm}.03 full visual resolution could not be reached photographically. Attention was called to the fact that on account of the slit width being limited by practical considerations to about one thousandth of an inch, two spectroscopes could be designed which would give exactly the same optical and photographic resolving power and contrasting power, while the ratio of focal length to aperture would in the one case be 1:12 and in the other 1:24.

The Third Conference of Astronomers and Astrophysicists was held at the Yerkes Observatory, September 6th to 8th. Cloudy weather prevailed most of the time, so that those in attendance were able to see but little with the great telescope. The following is a list of the papers read before the meeting :—

A. S. FLINT: The Repsold Transit Micrometer of the Washburn Observatory and Slat-Screen Apparatus.

S. J. BROWN: The Position of the Axis of *Neptune* from Perturbations of its Satellite.

E. E. BARNARD: Notes on the Annular Nebula in *Lyra*, the Fifth Satellite of *Jupiter*, Triangulation of Star Clusters, and Measures of the Difference of Declination of the Stars *Atlas* and *Pleione*.

WILLIAM HARKNESS: On the Semi-Diameters of the Sun and Moon.

F. R. MOULTON: Problems in Modern Celestial Mechanics Treated by the Use of Power Series.

ORMOND STONE: On the Motion of *Hyperion*.

E. C. PICKERING: The Revised Harvard Photometry.

KURT LAVES: Determination of the Principal Term of Nutation from Observations of *Eros*.

W. W. CAMPBELL: Wave-Length of the Green Coronal Line.

ASAPH HALL, Jr.: Aberration Constant from Meridian Zenith Distances of *Polaris*.

J. E. KEELER: The Ring Nebula in *Lyra*.

GEORGE E. HALE: Notes on Carbon in the Chromosphere, the Connection between Stellar Spectra of the Third and Fourth Types, and Some New Forms of Spectroheliographs.

E. B. FROST: Notes on the Reduction of Stellar Spectra, Titanium as a Comparison Spectrum, and Corrections of Absolute Wave-Lengths due to the Earth's Motion.

FRANK SCHLESINGER: Suggestions for the Determination of Stellar Parallax by Means of Photography.

S. I. BAILEY: Note on the Relations between the Visual and Photographic Light Curves of Variable Stars of Short Period.

S. I. BAILEY: The Periods of the Variable Stars in the Cluster *Messier 5*.

H. S. DAVIS: A Statement of the Progress of the New Reduction of PIAZZI's Meridian-Circle Observations between 1792 and 1814.

W. W. CAMPBELL: The Spectroscopic Binaries *Capella* and *Polaris*.

F. L. CHASE: Refraction of Red Stars.

GEORGE C. COMSTOCK: Some Researches in Stellar Color.

KURT LAVES: Inner Potential Forces Applied to Celestial Mechanics.

F. R. MOULTON: Laplace's Ring Nebular Hypothesis.

G. W. HOUGH: On the Actinism or Photographic Power of the Moon in a Total Eclipse.

M. B. SNYDER: The Phonochronograph and its Advantages in certain Astronomical Observations.

One of the astronomers present has kindly furnished us with the following notes concerning the papers:—

Dr. LAVES, in his paper, showed that the next opposition of the planet *Eros* would present a very favorable opportunity for the determination of the principal term of the constant of nutation.

Professor KEELER's paper on the Ring nebula in *Lyra* was accompanied by lantern-slides made from the negatives of this interesting object taken with the Crossley reflector. Professor BARNARD called attention to the fact that a star which he had found at the limit of visibility with the 40-inch telescope was shown on the Crossley plate of two hours' exposure, and the plate seemed to show yet fainter stars.

Professor CAMPBELL's paper gave the results of his observations on *Capella* and *Polaris*. Both were found to be spectroscopic binaries. In the case of *Capella* the lines were doubled periodically, while in *Polaris* they were periodically displaced, showing motion about a dark body.

Professor BAILY's paper gave a table of periods and magnitudes of the variable stars in the cluster *Messier 5*. The fainter variable stars in this cluster have all nearly the same period—about half a day. They have nearly the same magnitudes, and the range from maximum to minimum is about one magnitude. Professor BAILY thinks that they must all have had the same period at one time, and that perturbations have since changed them. There was found to be no relation between the distance of the star from the center of the cluster and its period. These variables range from 14^m to 15^m.

Some of the researches discussed by Professors HALE and BARNARD in their papers have already been mentioned in the extracts from the *Vierteljahrsschrift*. Professor HALE gave in addition an account of his observations by which carbon was discovered in the chromosphere. Professor BARNARD gave also an account of his observations with the 40-inch telescope, at different temperatures, to see if the curvature of the large object-glass changed. Observations were made over a range of 106° of temperature and a shortening of the focus was found in the cold weather. An account of these observations was published in No. 462 of the *Astronomical Journal*.

At the third conference of astronomers and astrophysicists held at the Yerkes Observatory in September, a permanent organization was effected under the name of "The Astronomical and Astrophysical Society of America." One of the charter members has kindly forwarded us a copy of the constitution of the society, the salient points of which are contained in the following extracts:—

"The purpose of this Society is the advancement of astronomy, astrophysics, and related branches of physics."

"Those persons whose names were signed on or before September 15, 1899, to the annexed statement of desire to form such an association shall constitute the charter members of this Society. Other persons may be elected to membership in the Society by the Council hereinafter provided."

"The officers of the Society shall consist of a president, two vice-presidents, a secretary, and a treasurer. . . . These officers together with four other members of the Society shall constitute a Council to which shall be intrusted the management of all affairs of the Society not otherwise provided for."

"The Council shall determine the time and place of each meeting of the Society, and shall provide for an annual meeting, at which officers shall be elected."

"The Council shall levy an annual assessment upon the members of the Society sufficient to provide the funds required by the Society for the ensuing year; provided that this assessment shall not exceed the sum of five dollars per member in any year."

The officers elected are as follows:—

President SIMON NEWCOMB, Washington, D. C.

Vice-Presidents, { CHARLES A. YOUNG, Halsted Observatory.
GEORGE E. HALE, Yerkes Observatory.

Secretary GEORGE C. COMSTOCK, Washburn Observatory.

Treasurer C. L. DOOLITTLE, Flower Observatory.

Other members of Council: E. C. PICKERING, Harvard College Observatory; JAMES E. KEELER, Lick Observatory; E. W. MORLEY, Adelbert College; ORMOND STONE, Leander McCormick Observatory.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD AT THE LICK OBSERVATORY, SEPTEMBER 2, 1899.

Dr. KEELER presided. A quorum was present. The minutes of the last meeting were approved.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD AT THE LICK OBSERVATORY,
SEPTEMBER 2, 1899.

Dr. KEELER presided. The minutes of the last meeting were approved.

The following papers were presented :—

1. The Rise and Progress of Astronomy in Central Europe (II), by SIDNEY D. TOWNLEY.
2. Photographic Observations of Comet *a*, 1889, (SWIFT), by E. F. CODDINGTON and H. K. PALMER.
3. Physical Changes Observed in the Head of SWIFT'S Comet, by C. D. PERRINE.
4. Observation of SWIFT'S Comet (1889 *a*) for Refraction, by C. D. PERRINE.
5. The Radiant Points of Meteors, by W. H. S. MONCK.
6. Elements of Comet 1898 VIII (CHASE), by R. SPRAGUE.
7. Planetary Phenomena for September and October, 1899, by Prof. M. McNEILL.

THE CHABOT OBSERVATORY—DOLBEER ECLIPSE EXPEDITION.

Secretary ZIEL reported that a committee, consisting of Messrs. JOHN DOLBEER and F. R. ZIEL, had been appointed by President PARDEE, for the purpose of procuring the funds necessary to defray the expenses of the Total Solar Eclipse Expedition to be undertaken by Mr. CHARLES BURCKHALTER in May, 1900,—and that Mr. JOHN DOLBEER has generously contributed the entire amount.

Adjourned.

OFFICERS OF THE SOCIETY.

MR. GEORGE C. PARDEE	President
MR. JAMES E. KEELER	First Vice-President
MR. CHARLES BURCKHALTER	Second Vice-President
MISS R. O'HALLORAN	Third Vice-President
MR. C. D. PERRINE	Secretaries
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MR. F. R. ZIEL	
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OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

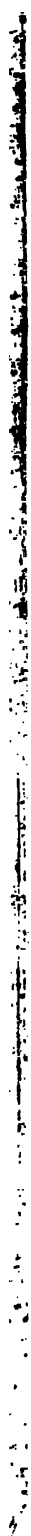
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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THE POTSDAM OBSERVATORY.

PUBLICATIONS.

1877-1878.

Astronomical Society of the Pacific.

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A REVIEW.

By SAMUEL D. FORTNEY.

Beobachtungen an der astronomischen Repeating, an einer Schenkung der Stadt von München und Trier, während der Zeit vom November, 1871, bis October, 1872, auf der Kordel, der absoluten Permutation von 100 astronomischen Stunden. VON DR. JULIUS BAUSCHINGER. *Abhandlungen der K. Sternwarte in München, Band III, 1873.*

In ascending the theory of refraction to a class of astronomical instruments in practical astronomy last spring, the above investigation was followed in considerable detail, as an illustration of the methods and results in the subject of refraction. The subject is, of course, an important one, and although numerous investigations have already been made, and accurate and convenient tables have been computed, still it has not reached the complete class demanded by the astronomy of precision of to-day. An interesting consequence, one of which have a direct bearing upon the construction of meridian-circle lenses, were reached, it has been thought that a review of the memoir may not be without interest to astronomical readers.

The first six articles are given up to a description of the instrument and an investigation of its circle and telescope, etc.

The instrument used was a new Repsold meridian-circle, with an objective of 16.6" (about 0.3 inches).

The purpose of the work was to thoroughly investigate, so far as circumstances would permit, all questions of astronomical refraction. Inseparably connected with this was a new determination

of the latitude and the compilation of a catalogue of fundamental declinations of a list of fixed stars. As to the usefulness of such a work, the author remarks (article VII, page 500): "Für



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ANNUAL REPORT.

FOR THE YEAR 1891.

Presented at the Annual Meeting of the American Association for the Advancement of Science, held at New York, September 1-10, 1891. Published by the American Association for the Advancement of Science, New York, 1891. By permission of the American Association for the Advancement of Science, New York, 1891.

Following the theory of our former annual reports, the present report is devoted to a general survey of the progress of astronomy during the year 1891.

Secondarily, the report is devoted to a survey of the progress of astronomy during the year 1891. The report is divided into two parts. The first part is devoted to a survey of the progress of astronomy during the year 1891. The second part is devoted to a survey of the progress of astronomy during the year 1891. The report is divided into two parts. The first part is devoted to a survey of the progress of astronomy during the year 1891. The second part is devoted to a survey of the progress of astronomy during the year 1891.

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utility of such an investigation cannot be doubted; for, aside from the fact that an investigation of the refraction in Munich has never been made, and observatories in which fundamental measurements are to be carried out can scarcely longer forego this work, the excellence of the new instrument also promised a higher degree of accuracy than was obtained by BESSEL in his investigation made seventy years previously. The experiences of the last decades have so often pointed to the necessity of change in the fundamentals adopted by BESSEL, that, from the present standpoint of instrumental equipment and accuracy of observing, a thoroughgoing investigation seems necessary, in order to obtain the greatest possible control over this most disturbing factor in astronomical observations. Besides this, advances which have not yet been utilized have been made in the mathematical treatment of refraction, as well as our knowledge of the atmosphere; and further, several questions of detail, such as the influence of the temperature of the observing-room, the humidity of the atmosphere, etc., seem hardly to have been sufficiently investigated."

The author makes here no reference to several investigations more recent than those of BESSEL.

The stars used in the investigation were taken from AUWERS'S "Fundamental Catalogue," in order to have a control upon the positions deduced, and also to lessen the labor of reduction, by using the proper motions there deduced. Polar stars were observed, at both upper and lower culmination, in all positions from the zenith to the northern horizon. Some stars culminating south of the zenith were also observed. In order to concentrate all the attention upon zenith-distances, no observations of Right Ascension were made. Something over four thousand observations were secured, on a list of two hundred and one stars, counting lower culmination as a separate star. Six hundred and fifty-eight culminations at a zenith-distance greater than 80° , and two hundred and seventy at a zenith-distance greater than 85° , were observed.

In the eighth article the meteorological data are fully discussed. In an investigation of this nature the manner of taking and working up the meteorological observations is a matter of the greatest importance. The first reduction of the zenith-distance observations was made by means of the RADAU'S tables ("Essai sur les Réfractions Astronomiques," *Memoires de l'Observatoire de*

Paris, t. XIX), which are convenient of application and accurate for large zenith-distances. The treatment of the meteorological observations was made along lines suggested in this memoir.

The barometer-readings besides being corrected for temperature of the mercury, the change in gravity with the latitude and the height above sea-level, were also corrected for the humidity of the atmosphere in the following way. FIZEAU and JAMIN have shown that the index of refraction for moist air is less than that of dry air, and such as would be produced by reducing the density in the ratio of 1 to $1 - \frac{1}{8} \frac{\pi}{760}$, where π is the absolute water-vapor tension in millimeters. If the index of refraction of dry air were determined and lay at the foundation of the tables, then for a vapor-tension of π the correction to the refraction could be brought about by a correction to the barometer-reading of $-\frac{1}{8} \frac{\pi}{760} B$. RADAU used, however, the index of refraction determined by BESSEL at Königsberg under a mean vapor-tension of 6^{mm}; hence the barometer-readings require only the correction $\frac{6-\pi}{8} \frac{B}{760}$.

The outside temperature was measured by means of a mercury centigrade thermometer hung in an open metal house outside the north window of a room near the meridian-circle room. The thermometer stood one meter from the wall and two and one-tenth meters from the ground. Toward the latter part of the observations an "Assmann'sches Aspirationsthermometer" (a thermometer past which a current of air is continually drawn) was used also, but no systematic difference was found between its readings and those of the other thermometer.

The temperature of the observing-room was very carefully taken by means of five thermometers suspended near the meridian-plane of the instrument. These were always read at the same time as the outside thermometer. It was found that the southern part of the room was warmer than the northern, which is to be explained probably by the greater heating of the southern walls (stone or brick). An investigation of all the readings of two years gave the following differences between inside and outside temperatures, taken in the sense inside minus outside:—

Nights	+ 1° .3
Mornings— Winter . .	+ 1 .3
Summer . .	- 0 .4
Afternoons— Winter . .	+ 1 .0
Summer . .	+ 0 .4

The differences were least with a strong wind, and greatest in calm weather.

The direction and velocity of wind and wet-bulb thermometer were also observed.

Article X is given up to the determination of the latitude and its variation. This can be done easily with a meridian-circle by observations of polar stars at upper and lower culmination, provided the division-errors of the circle have been well determined. For the Munich instrument this was done only for the 5° marks; and as the errors appeared to be purely accidental, it was impossible to interpolate for other divisions. A first approximation to the latitude was found from the numerous observations of α *Ursa Minoris* and γ *H Draconis*. The final value of the latitude, however, and its variation were only found after a number of approximations in which were used all of the stars which were observed at both upper and lower culmination.

With the value of the latitude and its variation so deduced, a table of preliminary declinations was derived from the observed zenith-distances.

The mean errors of the observations are derived in Article XII.

We have considered thus far only preliminary operations,—the preparation of the material for the discussion of the questions which it was proposed to investigate. The first taken up, Article XIII, is the coefficient of expansion of the air and the influence of vapor-tension. Some interesting results were derived.

In RADAU'S tables, REGNAULT'S value of the coefficient of expansion is used, namely:—

$$a = \frac{1}{273} = 0.003663 \text{ (for centigrade).}$$

The following investigation seemed to lead, at first, to a considerable correction. For this only stars between zenith-distances of 60° and 85° north were used, because those of a smaller zenith-distance can bring only a minimum consideration to the solution of the problem, while those of a large zenith-distance involve perturbations of such magnitude as to swallow up any influence from small changes of temperature.

For each star the mean of the four zenith-distances at the highest temperature were taken; likewise the mean of the zenith-distances at the four lowest temperatures; likewise the mean of the temperatures. The differences of temperature are for the

most part large, and valuable results should be expected. The differences $z_1 - z_0$ are in general but little larger than their mean errors, but the greater portion of them are positive, thirty-five out of forty-five. The cause of this discrepancy was sought in the coefficient of expansion. If $1 + \frac{i}{100}$ is the factor by which the coefficient of expansion, 0.003663, is to be multiplied, and if R is the refraction for 0° C. and 718^{mm} barometer, then, neglecting terms of the second order, we have observation-equations of the following form:—

$$(t_1 - t_0) 0.003663 \frac{R}{100} i = z_1 - z_0$$

Forty-five equations combined by the Methods of Least Squares gave

$$i = + 3.19 \pm 0.91$$

and hence for the coefficient of expansion,—

$$0.003663 (1 + 0.0319) = 0.003780 \pm 0.000033$$

This increase of three per cent. seems inadmissible, notwithstanding the fact that other investigators have found equally large results. For instance,—

GYLDÉN, 0.003769, *Obs. de Poulkova*, t. II, p. (16)

NYRÉN, 0.003770, “ “ “ Ser. II, t. I, p. (2)

MASCART, 0.00382 *Ann. d'Ecol. norm.*, 2. S. VI, 9

Neglecting the vapor-tension made the differences $z_1 - z_0$ “more positive.” This emphasized the necessity of taking the vapor-tension into account, and also seemed to indicate that the vapor-tension factor had not been correctly computed. As already pointed out, RADAU used the expression

$$\left(1 - \frac{1}{8} \frac{\pi}{760}\right) B \text{ instead of } B$$

where the empirical factor $\frac{1}{8}$ is taken from the experiments of FIZEAU and JAMIN, and depends upon the so-called optical density of the air. Theoretically, this distinction between optical and physical density is justified, and the only question is, Is this optical density to be used in astronomical observations where the conditions are essentially different from those of an experiment in the physical laboratory? To answer this, the coefficient of π was computed directly from the observations. This leads us back to the differences $z_1 - z_0$, because in general the extremes of temperature correspond to the extremes of vapor-tension.

If $\frac{k}{8}$ is the factor to be determined, then the equation is of the form

$$0.12 m (\pi_1 - \pi_0) (k - 1) = z_1 - z_0$$

where m means the change of refraction for 1^{mm} of mercury pressure (to be taken direct from RADAU'S tables). The solution of the forty-five equations gave

$$k - 1 = 3.37 \pm 0.69$$

The observations then decide in favor of a coefficient of π , which proves that the refraction depends upon the physical density of the air.

This is known, namely:—

$$\left(1 - 0.378 \frac{\pi}{760}\right) B, \text{ or nearly } \left(1 - \frac{3}{8} \frac{\pi}{760}\right) B$$

The remaining errors bear no systematic relation either in an arrangement according to zenith-distance or Right Ascension, from which was inferred, *that after the introduction of the new coefficient of π , the observations do not demand a change in the adopted value of the coefficient of expansion.*

The constant of refraction (Article XIV) was deduced from the declinations obtained from upper and lower culminations, without reference to the conclusions reached in the preceding article. Let

δ = declination from upper culmination

δ' = " " lower "

r = refraction for upper "

r' = " " lower "

$\Delta \phi$ = correction to the latitude employed

$1 + n$ = the factor by which the refraction employed (BESSEL'S constant) is to be multiplied in order to satisfy the observations at hand;

Then

$$\delta - \delta' = -2 \Delta \phi \pm r n - r' n \begin{cases} \text{upper cul. north of zenith} \\ \text{" " south " "} \end{cases}$$

Putting $-2 \Delta \phi = x$, $-100 n = y$, then

$$\delta - \delta' = x + y \frac{\pm r + r'}{100} \begin{cases} \text{upper culmination north of zenith} \\ \text{" " " south " "} \end{cases}$$

From the observation data, weighted observation-equations were formed by this formula, for all stars observed at both upper and lower culmination. The coefficient $\frac{\pm r + r'}{100}$ was taken direct from the values of the refraction employed.

The solution of these equations gave

$$\begin{array}{ll} x = -0''.797 & \text{weight } 163.08 \\ y = +0.510 & \text{" } 1053.92 \\ [P \Delta \Delta] = 140''.18 & \end{array} \left. \vphantom{\begin{array}{l} x \\ y \\ [P \Delta \Delta] \end{array}} \right\} \text{I.}$$

The considerable reduction in the value of BESSEL'S constant of refraction, indicated in the large value of y , must be taken with "*Vorsicht*," notwithstanding its large weight and the fact that other recent investigations have given similar results. An inspection of the observation equations showed that if the observations are taken only to 76° zenith-distance, no appreciable change would result in either the latitude or constant of refraction. Such a solution gave:—

$$\begin{array}{ll} x = -0''.047 & \text{weight } 29.79 \\ y = -0.028 & \text{" } 70.52 \\ [P \Delta \Delta] = 48''.90 & \end{array} \left. \vphantom{\begin{array}{l} x \\ y \\ [P \Delta \Delta] \end{array}} \right\} \text{II.}$$

The equations below 76° zenith-distance gave

$$\begin{array}{ll} x = -0''.575 & \text{weight } 19.30 \\ y = +0.483 & \text{" } 323.28 \\ [P \Delta \Delta] = 67''.87 & \end{array} \left. \vphantom{\begin{array}{l} x \\ y \\ [P \Delta \Delta] \end{array}} \right\} \text{III.}$$

It was found impossible to reconcile these last two solutions, and the inference is that there is some important factor, affecting the observations at large zenith-distances, not yet taken into account. It was thought that this discrepancy might lie in the law of decrease in the temperature of the atmosphere, by which undoubtedly the observations below 76° zenith-distance are influenced, while it is known that the refraction for stars of a smaller zenith-distance than 76° is practically the same, no matter what law of the constitution of the atmosphere is assumed. RADAU'S tables are computed upon IVORY'S hypothesis with the factor $f = 0.2$.

If the true value of f be taken to be $\frac{2+z}{10}$, then the change in the refraction will be $-\lambda z$, in which λ can be taken from table V, RADAU, and the observation equations then take the form—

$$\delta - \delta' = x + y \frac{z + z'}{10} + \lambda z$$

The solution of these equations gave

$$\begin{array}{ll} x = -0''.828 & \text{weight } 126.2 \\ y = +0.527 & \text{" } 672.1 \\ z = -0.053 & \text{" } 188.6 \\ [P \Delta \Delta] = 138''.65 & \end{array} \left. \vphantom{\begin{array}{l} x \\ y \\ z \\ [P \Delta \Delta] \end{array}} \right\} \text{IV.}$$

The introduction of z did not materially better the situation; moreover, the small value of z shows that no appreciable change in $f=0.2$, is demanded by the observations.

It was then thought than an explanation of the discrepancy might lie in the fact that at great zenith-distances the star-image is drawn out into a spectrum, and we can get from these observations an index of refraction for white light, which obtains for stars at, small zenith-distances, only when a particular part of the spectrum is set upon. In order to investigate this, the index of refraction was determined from solutions II and III, as follows:—

The observations were made with a mean barometer 718^{mm} and a mean temperature of $+5^{\circ}\text{C.}$; for these BESSEL'S constant of refraction, which has been used in the tables employed, is 56".076.

$$\begin{array}{ll} \text{From II} & +0.00028 \times 56''.076 = +0.016 \\ \text{" III} & -0.00483 \times 56''.076 = -0.271 \end{array}$$

whence we have for the two cases 56''.092, 55''.805. These quantities, for pressure 760^{mm} and temperature 0°C. , are 60''.461 and 60''.149, and the corresponding indices of refraction are—

$$\begin{array}{ll} \text{II.} & 1.0002933 \\ \text{III.} & 1.0002918 \end{array}$$

All these numbers correspond to a vapor-tension of 6^{mm}. KAYSER and RUNGE, through laboratory investigations, have found for the principal Fraunhofer lines (pressure 760^{mm}, temperature 0°C. , vapor-tension 6^{mm}).

$$\begin{array}{ll} \text{A} = & 1.0002902 \\ \text{B} = & 1.0002908 \\ \text{C} = & 1.0002911 \\ \text{D} = & 1.0002919 \\ \text{E} = & 1.0002930 \\ \text{F} = & 1.0002940 \end{array}$$

The value II above lies in the green, while the value III, for stars at great zenith-distances, lies between the red and yellow; a result to be expected on account of atmospheric absorption. The conclusion is that stars culminating at great zenith-distances are not suitable for the determination of the constant of refraction. Stars to about 80° can be used. Very small zenith-distances must also be used; otherwise the separation of x and y will be impossible. With these assumptions, another solution was made, and gave

$$\left. \begin{array}{ll} x = -0''.685 & \text{weight } 58.79 \\ y = +0.442 & \text{" } 18.43 \\ [\text{P } \Delta \Delta] = 82''.92 \end{array} \right\} \text{V}$$

This is nearly the solution I, and not more satisfactory.

As far as BAUSCHINGER could see, there was only one other possible way of explaining away these discrepancies, and that was through the *difference in temperature between the observing-room and the outside air*. This was investigated as follows :—

From the theory of refraction —

$$R = \int_1^{\mu_0} \frac{\sin z}{\sqrt{\frac{\mu r}{\mu_0 r_0} - \sin^2 z}} \cdot \frac{d\mu}{\mu} \quad \left(\begin{array}{l} \mu = \text{index of refraction.} \\ r = \text{distance of layer from} \\ \text{center of Earth.} \end{array} \right.$$

Putting $\frac{\mu r}{\mu_0 r_0} = 1$, we have $(R) = \tan z \int_1^{\mu_0} \frac{d\mu}{\mu} = \tan z \log. \text{nat. } \mu_0$

which shows that the refraction depends almost entirely upon the condition of the atmosphere in the lowest layer of the air. Where is this last layer? *In the observing-room*, just before the rays enter the telescope. The inference is that the inside, rather than the outside, temperature must be used. This, however, cannot be done so easily, because at the limit of the room the parallelism of the layers is destroyed. Through the following process an approximation can be reached: Conceive two layers, one corresponding to the outer temperature, one to the inner. At the dividing-line between them a new refraction takes place. To compute this it is necessary to know the form of the dividing-surface. Only when it is a cylinder whose axis is coincident with the rotation-axis of the instrument would no refraction take place. This in general will not be the case. The limit will correspond to the outline of the observing-room, and we must assume that the inner temperature is largely controlled by the radiation of the walls. If we assume this, then there will be two cases: one when the rays come in the top opening, the other when they enter through the side opening. The upper opening can be considered parallel to the general layers, and the refraction here will take place according to the same laws as in general. Let z' and z_0 be the zenith-distance of the outer and the measured rays; μ' and μ_0 the index of refraction for outer and inner air; ρ' and ρ_0 the densities; then we have, according to the law of SNELLIUS,—

$$\frac{\sin z'}{\sin z_0} = \frac{\mu_0}{\mu'} = \sqrt{\frac{1 + 2c\rho_0}{1 + 2c\rho'}}$$

$$\text{or, } \frac{\sin^2 z_0 - \sin^2 z'}{\sin^2 z_0} = \frac{2c\rho'}{1 + 2c\rho'} - \frac{\rho_0}{\rho'} \cdot \frac{2c\rho'}{1 + 2c\rho'} = 2a' \left(1 - \frac{\rho_0}{\rho'}\right),$$

where $a' = \frac{c \rho'}{1 + 2 c \rho}$ is the constant of refraction.

If we put further $z_0 - z' = R_s$ and

$$1 - \frac{\rho_0}{\rho'} = \frac{m(t_0 - t')}{1 + m t_0} \left\{ \begin{array}{l} m = \text{coefficient of expansion of the air} \\ t_0 = \text{inner temperature} \\ t' = \text{outer} \quad \text{"} \end{array} \right.$$

then we have, expanding and neglecting second and higher powers of R_s ,—

$$R_s = \left(\frac{m a'}{1 + m t_0} \tan z_0 \right) (t_0 - t')$$

The part in first brackets is the temperature coefficient, and we can thus compute the difference between outside and inside refraction.

For the side-walls the refraction is perpendicular to that just considered; and we therefore have

$$\frac{\cos z'}{\cos z_0} = \frac{\mu_0}{\mu'} \text{ and in a way similar to that just employed}$$

$$R_s = - \frac{a' m}{1 + m t_0} \cot z_0 (t_0 - t') = - \left(\frac{a' m}{1 + m t_0} \tan z_0 \right) \cot^2 z_0 (t_0 - t')$$

If z = the true zenith-distance, the quantity ultimately sought,

z' = the opponent zenith-distance of the rays at opening of shutter,

R = refraction computed with outside temperature,

z_0 = measured zenith-distance,

R_s = refraction in observing-room given by above formulæ;

then, $z = z' + R$,

$$z_0 - z' = R_s, \text{ or } z' = z_0 - R_s,$$

$$z = z_0 + R - R_s.$$

In the Munich meridian-circle room the dividing line between top and side openings is at about 60° zenith-distance, necessarily somewhat indeterminate on account of the thickness of the walls.

After applying the corrections R_s , and forming new quantities, $\delta - \delta'$, a new solution from all stars was made, and gave the following results:—

$$\left. \begin{array}{ll} x = -1''.018 & \text{weight 119.2} \\ y = +0.553 & \text{" 603.1} \\ z = +0.033 & \text{" 90.5} \end{array} \right\} \text{VI.}$$

[P Δ Δ] = 111.18

Using only stars to 76° zenith-distance, gave

$$\left. \begin{array}{ll} x = -0''.912 & \text{weight 29.79} \\ y = +0.445 & \text{" 70.52} \end{array} \right\} \text{VII.}$$

[P Δ Δ] = 54.19

A comparison of these two sets shows that there is no longer a "*Widerspruch*" between the results from small and large zenith-distances. The observations to 76° zenith-distance are represented through VI just as well as by VII. The [P Δ Δ] in the two cases being $55''.77$ and $54''.19$.

No other way of handling this temperature difference was apparent. Finally, then, to obtain the constant of refraction it was necessary to bring in the correction for water-vapor, which was shown to be necessary.

The refraction is to be computed with the expression, $B + \frac{k}{8} \cdot \frac{6 - \pi}{760} B$, instead of B .

The factor k was found to be 4.37 ± 0.69 . Instead of this value, however, which was not determined with great certainty, the value obtained by laboratory methods (namely, $k = 3$) was used.

With the finally corrected values of $\delta - \delta'$ a new solution gave;
All stars :—

$$\begin{array}{rcl} x = -1''.036 & \text{weight } 157.86 & \\ y = +0.563 & \text{" } 999.43 & \\ \text{[P } \Delta \Delta] = 140.88 & & \end{array} \left. \vphantom{\begin{array}{r} x \\ y \\ \text{[P } \Delta \Delta] \end{array}} \right\} \text{VIII.}$$

Stars down to 76° zenith-distance :—

$$\begin{array}{rcl} x = -0''.953 & \text{weight } 29.79 & \\ y = +0.491 & \text{" } 70.52 & \end{array} \left. \vphantom{\begin{array}{r} x \\ y \end{array}} \right\} \text{IX.}$$

The solution IX differs but little from VIII, and, on account of small weight, can be considered identical with it. VIII differs but little from VI. Solution VIII was considered final.

For 718^{mm} (at 0° C.) mercury pressure, $+5^\circ$ C. temperature, and 6^{mm} vapor-tension, BESSEL's constant of refraction is, according to RADAU's tables, $56''.076$. This requires now the correction $56''.076 \times 0.00563 = -0''.315$, giving thus $55''.761$. This gives for 760^{mm} pressure, 0° C. mercury temperature, 0° C. air temperature, and 6^{mm} vapor-tension, $60''.104 \pm 0''.025$. The corresponding index of refraction for the air is $1.00029152 \pm 0.00000012$. The correction to the latitude is $\Delta \phi = +0''.518 \pm 0''.056$.

With the corrected value of latitude, the corrected constant of refraction, the corrections for refraction in observing-room, and humidity of atmosphere, a new table of definitive declinations was computed.

Another investigation of interest, although without theoretical

foundation, was carried out. It was seen that the large differences between upper and lower culmination at great zenith-distances would disappear if a temperature about 1° higher had been used in computing the refraction. The temperature of the observing-room was in general about 1° higher than outside. The refraction was computed direct with the temperature of the observing-room, and again the differences $\delta - \delta'$ formed. The solution was again carried through, and gave:—

$$\begin{array}{rcl} x = -0''.419 & \text{weight } 157.86 & \\ y = -0.194 & \text{" } 999.43 & \end{array} \left. \vphantom{\begin{array}{rcl} x = -0''.419 \\ y = -0.194 \end{array}} \right\} X.$$

The outstanding errors, both in sign and magnitude, are very nearly the same as in VIII, so that this criterion will throw no light upon the question as to which is the correct method of procedure; but according to the above theoretical considerations, the solution X is to be thrown out. The work is not, however, entirely useless, because it shows to what an extent our declination systems are dependent upon the manner in which the temperature is measured.

BAUSCHINGER here states, as his opinion, with the emphasis of italics, that an absolute system of observations to be wholly free from objections must be made in the open air. The German loses much of its force in translation, and I therefore give the original statement.

"Meiner Ansicht nach ergibt sich hieraus die Forderung, dass völlig einwandfreie absolute Systeme ganz in freier Luft beobachtet werden müssen."

Another interesting investigation bearing upon the law of the decrease of the temperature in the atmosphere was carried out.

It is sometimes thought that a knowledge of the temperature in the upper layers of the atmosphere can be obtained from astronomical observations. This is true only to a very limited extent. Before this law can be ascertained, one must determine with great accuracy many factors which enter into it—chief of which are the constant of refraction and its dependence upon the part of the spectrum pointed upon, the coefficient of expansion of the air, the humidity, and above all the temperature of the last layer of air. To separate the effect of each one of these factors is considerable of a problem, as RADAU's extensive calculations have shown. BAUSCHINGER made some observations and calculations in the hope of throwing light upon the subject.

The observations can be satisfied by many different laws, when corresponding changes are made in the constant of refraction.

Comparison of IVORY's hypothesis, as used by RADAU, and GYLDÉN's hypothesis and a combination of the two, leads to the following conclusion, namely: that the observations are represented equally well by either hypothesis:—

$$\begin{array}{l} \text{IVORY's hypothesis gives: } t_0 - t = 5^{\circ}.69 h - 0^{\circ}.19 h^2; \\ \text{GYLDÉN'S " " " } t_0 - t = 5.10 h - 0.025 h^2; \end{array}$$

where t_0 is temperature of lowest layer, t temperature of the layer at h kilometers above the ground.

Meteorological observations in balloons bear directly upon this subject. Perhaps in the future such experiments may bring valuable results, but thus far they have given little else than an extraordinary changeableness in the "law" of decrease of temperature, in the layers to about 2^{km} height.

Observations were made in Bavaria, at night, by Professors SOHNCE and FINSTERWALDER. For altitudes between 300 and 2,000 meters a decrease in temperature, 10° per km. in clear summer nights was found. Up to 300^{m} there is often, and always at night, an increase in the temperature.

As far as present evidence goes, it does not seem possible to improve on IVORY's hypothesis, up to an altitude of 10^{km} at least. The difference between actual observed temperatures and those given by the hypotheses of IVORY and GYLDÉN follows. The highest reading was at 16^{km} . From 10 to 16^{km} IVORY's hypothesis falls considerably short.

$$\begin{array}{l} \text{At } 16^{\text{km}} \text{ Obser. — IVORY} = + 27^{\circ} \\ \text{" " " — GYL.} = - 6 \end{array}$$

GYLDÉN's agreement is very good throughout. If these observations are confirmed by future experiments, IVORY's hypothesis must be abandoned, although it will be sufficiently exact to zenith-distance of 88° .

As already mentioned, the temperature on clear nights reaches a maximum at some distance above the Earth. From balloon observations and observations upon the Eiffel tower in Paris, it was found that the increase was about 2° C., and the maximum reached at about 200^{m} .

It is interesting to know the effect of this condition upon the refraction. RADAU investigated this through an elegant analysis,

which, however, leads to extensive calculations. The problem can be successfully handled by mechanical quadratures.

Consider the atmosphere divided into two parts, at the maximum temperature point. Assume the temperature to increase proportional to the distance in the first part, and to decrease according to IVORY'S law in the second part. The refraction in the second part can be computed from the ordinary tables, provided we know the height of the barometer at the altitude H , the separating line. This is easily found by the formula:—

$$H = 18401.2 \left(1 + \frac{T}{273}\right) \left(1 + \frac{3}{8} \frac{\pi}{P}\right) \left(1 + 0.0026 \cos 2\phi\right) \left(1 + 0.000000196 b \log \frac{P}{p}\right)$$

where T is mean temperature of the layer,

“ P is barometer height at ground,

“ p is “ “ “ H ,

“ b is height of ground above sea-level.

The refraction in the first part can be computed by

$$(R) = \int_{\mu_1}^{\mu_2} \tan z \frac{d\mu}{\mu}$$

The whole distance H is divided into layers, of say 10^m thickness.

Values of μ for every 10^m were computed, for certain atmospheric conditions, and then the processes of mechanical quadrature applied to the integral for certain special values of $\tan z$.

The results are as follows:—

z_0	$74^\circ 2'$	$79^\circ 4'$	$82^\circ 16'$	$84^\circ 7'$	$86^\circ 22'$	$87^\circ 56'$
(R)	$6''.08$	$9''.01$	$12''.82$	$16''.90$	$27''.44$	$48''.32$

In upper part (from tables):—

$((R))$	$3' 7''.04$	$4' 32''.87$	$6' 18''.15$	$8' 1''.74$	$11' 48''.02$	$16' 49''.55$
$R_a - R_n$	$3' 13''.12$	$4' 41''.88$	$6' 30''.97$	$8' 18''.64$	$12' 15''.46$	$17' 37''.87$

From tables with lower temperature:—

R_n	$3' 13''.06$	$4' 41''.65$	$6' 30''.34$	$8' 17''.32$	$12' 10''.38$	$17' 21''.51$
$R_a - R_n$	$+0''.06$	$+0''.23$	$+0''.63$	$+1''.32$	$+5''.08$	$+16''.36$

From the values of $R_a - R_n$ it is seen:—

1. That down to about 80° zenith-distance, the effect on the refraction, of the observed temperature inversion, is negligible.

It has already been found through other investigations that refractions cannot be relied upon below this limit.

2. That the above values of $\delta - \delta'$ would be still greater, and consequently BESSEL'S refraction constant still more decreased, if we should take into account the effect of this inversion of the temperature.

It appears from all these investigations that no condition of the atmosphere, consistent with the observed meteorological conditions, will explain away the differences $\delta - \delta'$. There seems, then, no escape from the conclusion that BESSEL'S constant of refraction must be decreased. Several other recent investigations lead to the same conclusion. A comparison of its value is made with all the previous determinations.

In the above review I have attempted only once to give an exact translation. Throughout, however, I have followed closely the author's order of presentation, and in many places have used nearly the exact language of the original.

One who studies the memoir cannot help but to be impressed with the thoroughness of the investigation and with the scientific attitude of the investigator. Apparently he has spared no labor, neglected no detail in his effort to obtain the correct interpretation from the data of observation.

The most important conclusions reached in the investigation are as follows:—

1. In investigations of this nature, and in all meridian-circle observations made to determine accurate zenith-distances, the manner of observing the temperature is of the utmost importance.

2. The difference between inside and outside temperature cannot be neglected. It is apt to be considerable, especially in the older form of meridian-circle houses, and is greatest in the best observing weather — calm.

3. The effect upon the refraction of the observed inversion of the temperature at night is negligible to a zenith-distance of 80° .

4. In computing the refraction at the shutters the form of the opening must be taken into account. To be entirely free from objection, observations for an absolute system should be made in the open air.

5. The humidity of the air must be taken into account in correcting the barometer readings. Other recent investigations have led to the same conclusion.

6. The astronomical refraction depends upon the physical density of the air, and not, as before assumed, upon the optical density.

7. Granting 6, then the Munich observations do not demand a change in the adopted value of the coefficient of expansion of air. A result which agrees with other (not all) recent investigations, laboratory as well as astronomical.

8. The Munich observations, as well as others, show the necessity of a considerable decrease in BESSEL'S constant of refraction.

PROGRAMME OF THE INTERNATIONAL GEODETIC ASSOCIATION FOR OBSERVING VARI- ATIONS OF LATITUDES.

BY FRANK SCHLESINGER.

The twelfth General Conference of the International Geodetic Association was held at Stuttgart, in October, 1898. A plan that had been under contemplation for several years for observing variations of latitudes was there formally adopted. Since then the observations have actually been begun and some of the details of the work may not be without interest.

I. SELECTION OF THE STATIONS.

The general aim of the association was to establish four stations on the same parallel of latitude, as well distributed in longitude as possible; to equip these stations with zenith-telescopes embodying some modifications that previous experience has indicated, and of larger aperture than usually employed; to so arrange the programme that all the observations at one station could be made by a single observer. It was of course necessary that each station should be located where there was a good average of clear nights, not only for the whole year, but for each season, in order to guard against a long interruption of the observations. It was deemed desirable that the character of the country should be the same to the north and to the south of each station, and that the seismological, hygienic, and social conditions should be good. With all these requirements to be considered,

it was by no means an easy task to select four suitable sites. After discussing many possible combinations of locations, the Central Bureau of the association finally fixed upon the following:—

	Longitude West of Greenwich.
Mizusawa, Japan, . . .	— 141°
Carloforte, Italy, . . .	— 9°
Gaithersburg, Maryland, . . .	+ 77°
Ukiah, California, . . .	+ 123°

Mizusawa* lies in the valley of the Kitakami River, and has a population of ten thousand. The station is half a mile south of the city, in latitude $39^{\circ} 08' 07''$. Carloforte has eight thousand inhabitants, and is the principal city on the small island of San Pietro, which lies just west of Sardinia, near its southern extremity. The latitude of the station will not differ greatly from $39^{\circ} 08' 12''$. Gaithersburg is a town of two thousand people, about twenty miles northwest of Washington. The station is about half a mile from the town, and is in latitude $39^{\circ} 08' 10''$. Ukiah is in the valley of the Russian River, and has two thousand eight hundred inhabitants. It is the terminus of a railroad which runs one hundred and twelve miles north from San Francisco, and is about thirty miles from the Pacific Coast; the station is a mile south of Ukiah, in latitude $39^{\circ} 08' 09''$.

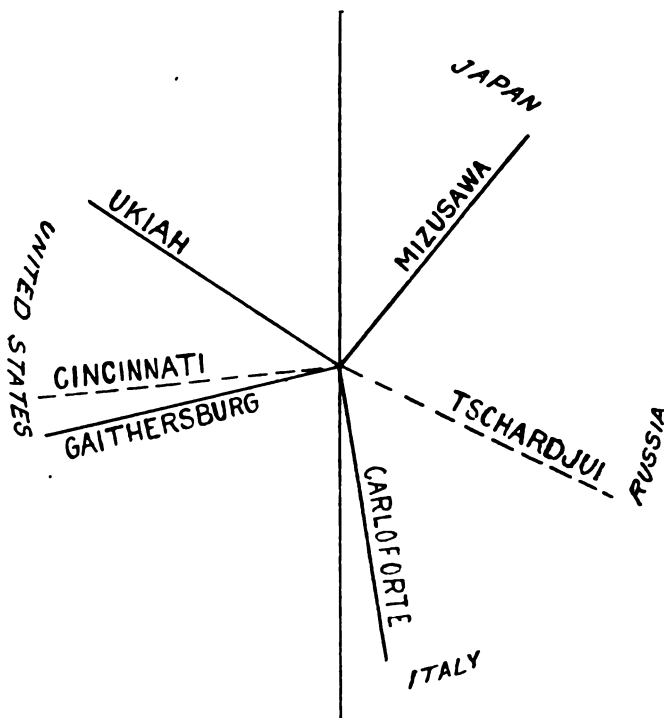
Thus two of the stations are in the United States; and in regard to these, the Superintendent of the United States Coast and Geodetic Survey has agreed to undertake the supervision, an arrangement which has been of the greatest benefit to the work.

The four stations established by the association are within a few seconds of the same parallel of latitude. By a mere coincidence Cincinnati Observatory, which is in longitude 84° west of Greenwich, is only a few hundred feet north of this parallel. The director of the observatory, Professor J. G. PORTER, has volunteered to take part in the programme, an offer which was readily accepted by the International Association. Furthermore, the Russian Government has also offered to equip and support a sixth station at Tschardjui, a city in longitude 64° east, on the River Amu-Daria (or Oxus), and on the required parallel. This addition is especially welcome, as otherwise there would be an arc of 133° between Carloforte and Mizusawa unprovided with a

*The writer is indebted for most of these details to the "Bericht über die Vorbereitungen für den internationalen Polhöhdienst," HELMERT and ALBRECHT, 1898.

station. It may be mentioned here that there is some possibility of the permanent removal to Tschardjui of the observatory which is now at Taschkent.

The distribution of all six stations is shown in the accompanying figure, the central line representing the meridian of Greenwich.



DISTRIBUTION OF THE STATIONS.

II. THE PROGRAMME FOR OBSERVING.

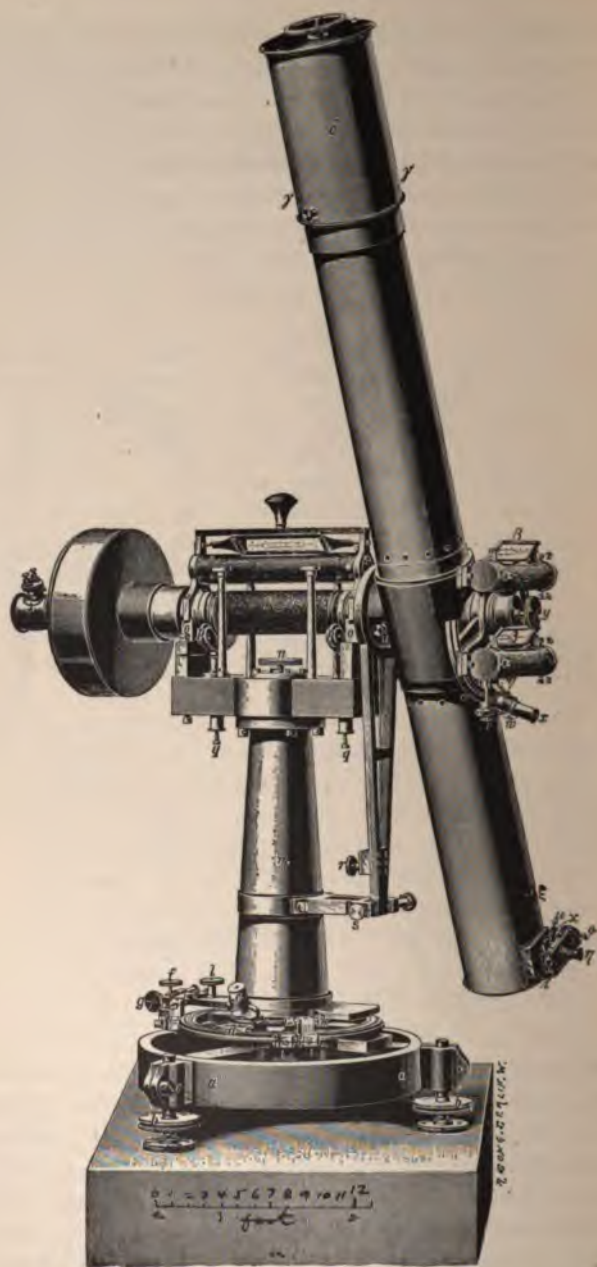
In arranging the programme for observing, the controlling desideratum has been to obtain the most accurate results for the variation of latitude solely, and not to attempt to use the observations for deducing the value of the constant of aberration. Following KÜSTNER's lead, in which he obtained the first conclusive observational evidence of a change in latitude, most other latitude observers have also sought to determine the aberration constant. Such a plan necessitates a limited number of groups, of which one at least must be observed during nearly the whole of the period in which it transits at night. The accuracy of the

resulting latitudes is thus lessened for two reasons; first, because there are periods when only one group can be observed, and, second, the latitude results will be more dependent upon the value adopted for the aberration constant. This follows from the very cause that would make such a series of observations valuable for determining the constant. The Central Bureau of the Association has decided to use no less than twelve groups, each extending over two hours of Right Ascension. Two consecutive groups are to be observed on each night as follows:—

Group.	R. A.	To be observed		Duration of	
		From	To	Group.	Group Connect'n.
I	0 ^h - 2 ^h	Sept. 23	Dec. 6	74 days	35 days
II	2 - 4	Nov. 2	Jan. 4	64	29
III	4 - 6	Dec. 7	Jan. 30	55	26
IV	6 - 8	Jan. 5	Feb. 24	51	25
V	8 - 10	Jan. 31	Mar. 21	50	25
VI	10 - 12	Feb. 25	Apr. 15	50	25
VII	12 - 14	Mar. 22	May 11	51	26
VIII	14 - 16	Apr. 16	June 8	54	28
IX	16 - 18	May 12	July 9	59	31
X	18 - 20	June 9	Aug. 13	66	35
XI	20 - 22	July 10	Sept. 22	75	40
XII	22 - 24	Aug. 14	Nov. 1	80	40

By "duration of group-connection" is meant the period in which the same two groups are observed: thus, Groups I and II are observed together during a period of thirty-five days; Groups II and III during twenty-nine days, etc. It will be noticed that these periods are short in the spring and long in the fall. This arrangement was adopted principally for the convenience of the observer, as the night's work is thus brought as nearly after sunset as was deemed safe. In midwinter, observing will begin not less than two and a half hours after sunset, while in midsummer this minimum interval is reduced to one and a half hours.

Each group contains eight pairs, only six of which, however, are to be used directly in determining the latitude. The two others are of very large zenith-distances, and were introduced, upon the suggestion of Professor HELMERT, in order to detect anomalous refractions. In the discussion of previous latitude observations such anomalies have often been appealed to, in order to account for some puzzling systematic discrepancies in the results. It has happened, for example, that the values of the latitudes from all the pairs on a certain night were greater than



THE ZENITH - TELESCOPE.

the true value. This result would be brought about if the index of refraction were greater to the south of the station than to the north. In the present programme such a condition of affairs will be revealed in the observations themselves for any single night, since there will be four pairs at about 60° zenith-distance while the latitude pairs exceed 20° zenith-distance in only three or four cases in all twelve groups.

The observing list therefore requires the selection of ninety-six suitable pairs, a far greater number than has usually been employed. Nevertheless, it has not been a very difficult task to make the selection because the instruments are of large enough aperture to permit the use of stars down to the seventh magnitude; and besides, accurate knowledge of proper motions, or even positions, of the stars is by no means necessary in the present case. A proper-motion effect cannot be confused with a variation of latitude, for the latter at any station has its counterpart, or rather its intaglio, at a station on the opposite meridian. For example, if the latitude of Ukiah should increase, then that of Tschardjui must decrease by practically the same amount, since these two stations differ nearly 180° in longitude. On the other hand, if the increase in the latitude of Ukiah should be only apparent and due to ignorance of proper motions, then the latitudes of all the other stations would be increased by the same amount. The observing list as actually constructed is an admirable one. The stars vary in magnitude from 4.0 to 7.0. The maximum difference of zenith-distances is about $16'$ for the latitude pairs, and only about $5'$ for the refraction pairs. The least interval between the transits of any two consecutive stars in the list is four minutes, allowing ample time for level readings before and after each transit.

III. THE ZENITH-TELESCOPE.

Each of the four principal stations has been furnished with an instrument like that shown in the accompanying drawing. Except as to its larger dimensions and three or four other points, this instrument does not differ from those formerly employed, but a brief description may not be amiss. The instrument rests on the three leveling-screws, *b*, on point, line, and plane bearings. The horizontal circle has a diameter of eleven inches, and may be read by means of two verniers to $10''$. Upon the circle are mounted two stops, *k*, which, having been set once for all, permit the instrument to be reversed 180° in a few seconds. Most of the weight

of the movable parts is supported by the adjustable springs, q , provided with friction rollers at p . Thus only a slight pressure is exerted upon the wyres, o .

The focal length of the telescope is fifty-one inches, though the tube is nine inches longer on account of the dew-cap, δ , the object-glass being at γ . The aperture is four and one quarter inches; but the tube is again somewhat larger in diameter, because it is double throughout its entire length, with an air-space between its two walls. The outer tube is pierced by a double row of ventilating holes, the idea being to guard against sudden changes of temperature and consequent flexure.

The levels, a , are extremely sensitive; they may be adjusted by the opposing screws, z , and the lengths of the bubbles may be regulated without removing either level from its fastenings. The vertical circle has a diameter of nine and one half inches, and is set by means of the clamp, v , and the tangent-screw, w ; when, however, the required reading has been obtained, the more powerful clamp, y , is applied, and the lower clamp is released. There is thus obtained a greater certainty of the constancy of the angle between levels and telescope. After the vertical circle is set the telescope is clamped at approximately the proper inclination by r , and the bubbles are then centered by the tangent-screw, s .

The eye-end is somewhat complicated. To the rear of the eye-piece is a focal scale, not visible in the drawing, ξ being the focus-clamp. The micrometer-head is at θ , and the field is centered by the opposite screw, λ . The collimation may be adjusted by two opposing screws, one of which is shown at v , and the inclination of the micrometer-head is also controlled by two opposing, of which k is one. The eye-piece itself, η , contains a reversing prism, so that the micrometer thread may be set apparently vertical (preferably), no matter what the inclination of the telescope may be. Furthermore, an ingenious device has been added by which the thread may be apparently reversed 180° by simply turning the outer part of the eye-piece from one stop to another, which is 90° distant. This outer part of the eye-piece is held in place by slight friction with the inner part; the latter is in turn held by somewhat greater friction to the telescope tube, so that the outer part may be turned without disturbing the inner, and either may be moved without changing the focus. The method of observing with this eye-piece is to set the outer part against one of its stops, then to turn the inner part till the microm-

eter thread appears vertical. When the star comes into view, two bisections are made before it reaches the middle of the field. The outer tube of the eye-piece is then turned against its other stop, and two more bisections are made before the star leaves the field. The effect is to make the star appear and disappear in the same part of the field, either at the top or at the bottom. From even the somewhat limited experience which the writer has had with this eye-piece, he is able to state that it constitutes no small improvement; not only on account of the greater accuracy which comes from holding the head in a comfortable position, but also because personality, in always setting the wire too far to the right; say, is thus eliminated from the measurements of each star.

In order to avoid as much labor as possible in determining the azimuths, collimation, etc., of the instrument, a meridian-mark is used. This consists of two targets separated by twice the eccentricity of the telescope, and mounted on a pier not less than fifty yards distant either to the north or to the south of the zenith-telescope. One of the targets is placed exactly in the meridian of the telescope when the latter is east of the vertical axis, and the other is to be in the meridian when the telescope is west. Their positions may be verified from time to time by star-transits. In order that the targets may be brought into focus without disturbing the collimation, an auxiliary lens is placed between the objective and eye-piece, and as near the latter as practicable. It is shunted into the optical axis by means of μ , and works against a stop so as always to come to the same place. The position of the lens is such as to make the likelihood of a change in collimation a minimum; but it should be remarked that this change need not be small if it remain constant during the short period between two consecutive tests of the targets for position. The presence of the auxiliary lens has suggested a method for determining the progressive and periodic errors of the micrometer-screw, which will be tried at Ukiah as soon as opportunity offers. A vertical scale may be supported on the meridian-mark pier, with spaces between its divisions to correspond with one turn of the micrometer-screw. The progressive errors of the screw and the division errors of the scale may then be determined simultaneously by the method variously accredited to GILL, LORENTZEN, LEMAN, and THRESSIN.* The periodic errors may be found by

* A good exposition of this method has been given by HAROLD JACOB, in the *American Journal of Science*, for May, 1896.

direct readings of a smaller scale, whose errors have first been determined by the above method. The writer believes that in this way more accurate results can be obtained in a given time than by employing circumpolar elongations. Besides, this work may be executed in the daytime or on cloudy nights.

As shown in the picture, the telescope is provided with electric illumination for the field, but this may very quickly be changed for oil or other illumination.

The chief constants of the instruments are as follows: Focal length, 51 inches; aperture, $4\frac{1}{4}$ inches; magnifying power, 104; one turn of micrometer-screw, 40"; least direct reading of micrometer, 0".4; least direct reading of levels, 1".0.

The micrometer-head may thus be read by estimation to 0".04, and the levels to 0".10.

The instrument was made by WANSCHAFF, of Berlin, with the optical parts by ZEISS, of Jena, and the levels by REICHEL, of Berlin.

IV. THE OBSERVATORY.

The following very brief description applies especially to the station at Ukiah; but the others are not different in any essential, except that perhaps some of the foreign observatories have been built of iron. All three* in this country are of wood.

The zenith-telescope pier is of brick, twenty-three inches square, and rests on a brick foundation four feet deep and five feet square. The floor and walls of the observatory are supported by a brick foundation-wall, which is as deep as the foundation for the pier; between the two is an air-space. On the outer edge of the foundation-wall rests a high wooden lattice thirteen feet square; on the inner edge is the observatory wall proper, leaving a well-ventilated space all around the observatory. The roof is made double, and is provided with ventilators projecting into the open air. The walls of the observatory are also pierced by four ventilators, two up high and two down low, so that the interior is

* The following details concerning the station at Cincinnati are taken from a letter from Professor PORTER, dated October 17, 1899: "A small observatory, modeled after the plans sent from Potsdam, but constructed of wood, was erected on the grounds of the Cincinnati Observatory, 19^m.0 west and 14^m.6 south of the center of the dome. The Superintendent of the United States Coast and Geodetic Survey kindly loaned us a zenith-telescope for the prosecution of this work. It is one of WANSCHAFF's instruments, constructed on the same general lines as the somewhat larger instruments built for the four main stations. The focal length is 1^m.00, aperture 81^{mm}, magnifying power 100. . . . It was not convenient to erect a collimator, and the instrumental constants are controlled by observations of stars. Practically, however, this gives no trouble, as the instrument is very steady. The use of a reversing prism was also found to be impossible with the fainter stars."

kept dry and at the same temperature as the atmosphere outside. The roof of the observatory is in two parts, one of which rolls east and the other west, leaving a clear opening of six feet. While observing, all other openings are closed, and if the wind is blowing too hard, the roof-opening is also contracted. The meridian-mark is viewed through a north door. The pier on which the mark is mounted is sheathed with tinning and protected by a wide lattice structure, so as to guard against warpings from the direct rays of the sun. A pendulum-clock, beating seconds, a self-registering barometer, and several other minor instruments have been provided for each station.

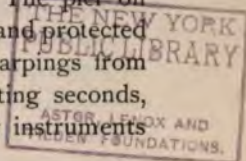
UKIAH, CALIFORNIA, 1899, Nov. 20.

THE *PERSEID* RADIANT.

BY W. H. S. MONCK.

MR. DENNING's recent paper in the *Memoirs of the Royal Astronomical Society* has, I think, placed beyond doubt that in the vast majority of cases meteors come from the same radiant point at different seasons of the year. The coincidences are far too numerous and too close to be the result of chance. There must, generally speaking, be some physical connection between the various meteors which Mr. DENNING classes together, and the duty of the physicist is not to ignore this fact, but to explain it. Theoretically,—I mean in accordance with the current theory,—all showers which last for more than one night ought to shift. But they do not. Mr. DENNING mentions but two shifting radiants—the *Lyrids* and the *Perseids*—and he is doubtful as to whether the apparent shifting of the former is real. He further points out that there is a permanent, or stationary, radiant almost coincident with both. This is a significant fact, and throws a difficulty in the way of proving the actual shifting. At all events, Mr. DENNING's catalogue justifies the assertion that stationary radiation is the rule, and shifting radiation the exception—if indeed there be any exception. This is the exact opposite of what the current theory would lead us to expect; and consequently the current theory must, I apprehend, be wrong.

My main object is, however, to deal with the *Perseid* radiant, which is the stronghold of all who believe in shifting radiants,



some of whom seem to me to forget that one swallow does not make a summer. Now, I wish to call attention in the first place to a peculiarity in this part of the sky. There is scarcely a spot in the region of *Perseus* and the adjoining parts of *Cassiopeia*, *Camelopardus*, and *Andromeda* from which meteors do not come to us at various seasons of the year. We seem here to have not a number of radiant points, but a radiant area. Most of the radiants in this part of Mr. DENNING's catalogue are, moreover, ill-defined. Some of the positions are at a considerable distance from the assigned center; and there is often no distinct line of demarcation between the meteors assigned to two adjacent centers. It is easy to prove this without referring to the radiants which Mr. DENNING refers to the great shifting *Perseid* shower. The R. A. of the forty-four radiants which he describes as "*a Cassiopeids*," with a center at $7^{\circ}.1 + 51^{\circ}.9$, varies from 0° to 16° , and the Declination from $+49^{\circ}$ to $+57^{\circ}$. The extremes for the " *δ Cassiopeids*," with a center at $19^{\circ}.2 + 57^{\circ}.7$, are R. A. 10° to 26° , and Decl. 51° to 65° . I need not specify the limits of other radiants in this region. They are all of the same description, and their classification is evidently to a large extent arbitrary. In the case of the two *Cassiopeid* showers, a radiant at $8^{\circ} + 55^{\circ}$ is placed under one head, and a radiant at $10^{\circ} + 56^{\circ}$ under the other. Both were observed in the first half of August. Radiants at $24^{\circ} + 50^{\circ}$ and $22^{\circ} + 49^{\circ}$ are classed as belonging to a center near γ *Andromeda*, whereas radiants at $20^{\circ} + 50^{\circ}$, $20^{\circ} + 52^{\circ}$, and $24^{\circ} + 52^{\circ}$ are classed as *δ Cassiopeids*. Radiants at $26^{\circ} + 48^{\circ}$ and $25^{\circ} + 46^{\circ}$ are referred to the *Andromeda* center, while one at $28^{\circ} + 45^{\circ}$ is described as a " *θ Perseid*." Mr. DENNING is himself doubtful whether the "*a Perseids*" constitute a distinct shower. The *η Perseids* include a position at $50^{\circ} + 54^{\circ}$, and the "*a Perseids*" one at $54^{\circ} + 54^{\circ}$. These " *η Perseids*," however, are even more closely connected with the " *χ Perseids*," the former containing positions at $39^{\circ} + 57^{\circ}$, and $40^{\circ} + 59^{\circ}$, and the latter at $36^{\circ} + 57^{\circ}$, $38^{\circ} + 59^{\circ}$, and $38^{\circ} + 60^{\circ}$. All these centers—two in *Cassiopeia*, one in *Andromeda*, and three or four in *Perseus*—are active not merely during July and August, but during a great part of the year. We have in fact a permanent, or stationary, radiant area in which some points seem to be peculiarly active, but no satisfactory reduction to a definite number of stationary radiants can be made.

It is, then, across this stationary radiant area that Mr. DENNING

thinks he can trace the path of a shifting shower lasting from July 11th to August 20th. It is not, I think, contended that the meteors belonging to this shifting shower possess any physical peculiarity by which they can be recognized. All meteors coming from this region of the sky are of the same swift, streaky kind. No point on the supposed track of the shifting shower becomes active for the first time when that shower reaches it, or ceases to be active as soon as the shower has passed over it; nor is the surrounding portion of the sky quiescent when the moving point is active. All therefore that could be proved is that a line can be drawn across this radiant area running nearly due east, the various points on which successively attain their *maximum* activity, the daily change in the position of the maximum being about 1° . The strength of the shifting shower would be measured at each point on this line by the excess of the activity on the night in question over the normal activity of the same point at this season of the year. Has Mr. DENNING proved the existence of these successive *maxima* all along his line?

It is most convenient to deal with the subject in sections. I begin with the period extending from July 11th to July 26th, inclusive. During these sixteen days Mr. DENNING has only been able to find seven radiants which he can refer to this shifting shower. Two of these seven positions are deduced from observations extending over several nights—one from the 8th to the 13th, and the other from the 22d to the 27th of July. This would be a very unsatisfactory course if the radiant were really shifting at the rate of 1° in R. A. for each night. He finds no position on the 14th, 15th, 16th, 17th, 20th, or 21st of July which falls in with the theory of shifting. The initial position at $11^{\circ}+48^{\circ}$ on July 11th (rather July 8–13th) falls within the region of the α *Cassiopeids*, which is then active. It is deduced from ten meteors. But I find an α *Cassiopeid* position at $11^{\circ}+50^{\circ}$ deduced from twenty-six meteors from July 21st to August 1st, and another at the same point from twenty-nine meteors on August 9–13th; consequently it would appear that this radiant, so far from attaining its maximum activity during the period July 8–13th, is more active a full month later. Why not, then, class this radiant at $11^{\circ}+48^{\circ}$ simply as an α *Cassiopeid*? It would no doubt be so classed if it occurred at any other date. The other radiant, which Mr. DENNING deduces from several days' observations, is at $23^{\circ}+49^{\circ}$ for the period July 22–27th.

No one can doubt, I think, that this is a different determination of the same radiant as HEIS's $24^{\circ}+50^{\circ}$ for July 22-25th, which Mr. DENNING classes as a " γ *Andromedid*." It might also, however, have been referred to the " δ *Cassiopeids*," which yield positions at $24^{\circ}+52^{\circ}$ and $25^{\circ}+51^{\circ}$, running insensibly into the *Andromeda* radiant, as usually happens in this part of the sky. The five remaining determinations rest on a single night's observations. They give $17^{\circ}+50^{\circ}$ for July 18th, $19^{\circ}+51^{\circ}$ for July 19th, $25^{\circ}+52^{\circ}$ for July 22d, and also for July 23d, and $22^{\circ}+52^{\circ}$ for July 25th (where it will be seen that the change of 3° from its immediate predecessors is in the opposite direction from what the shifting theory requires). All five positions lie within the limits of the δ *Cassiopeids*, which are active both before and after; and as none of them are deduced from more than five meteors, the normal activity of the δ *Cassiopeids* at this time of the year seems sufficient to account for them. Up to the 27th of July there seems to me to be no proof of the existence of any shifting radiant in *Cassiopeia* or *Perseus*.

From this date to the middle of August the observations become more frequent, but they are still all referable to centers of radiation which are active both before and after. A remarkable instance of this kind meets us at the outset. Mr. DENNING gives three determinations of the shifting radiant at $32^{\circ}+53^{\circ}$ for July 28th, July 30th, and July 31st, respectively. Taking a mean between these and certain other radiants observed on the same days, a shifting appears to result; but it is not the less true that meteors reach us from what appears to be a rather sharply defined radiant at $32^{\circ}+53^{\circ}$ for four days in succession. Further, on turning to the " θ *Perseids*," I find the position $32^{\circ}+53^{\circ}$ set down for the period July 25th-August 1st. Surely this is merely a different observation of the same shower that has been already referred to the shifting radiant. The other positions of the shifting radiant at this period agree closely with those given under the head of " θ *Perseids*," " χ *Perseids*," and " η *Perseids*." I am not blaming Mr. DENNING for thus mixing up the meteors belonging to the supposed shifting radiant with others belonging to stationary radiants situated in the same part of the sky. This is in fact inevitable. Let us suppose that the normal activity of a given radiant is represented by three meteors per night, while the effect of the shifting radiant passing over it is to add three meteors for the night of passage. The radiant for that night will

be determined from six meteors, three of which belong to the fixed and three to the movable series. But then the real question in each case will be, Is the normal activity of the radiant clearly exceeded at the date assigned to the passing of the shifting radiant over it? For it is only by means of the addition thus made to the normal activity that the existence of the shifting shower can be proved at all.

That the normal activity of the main radiant situated at about $44^{\circ}+56^{\circ}$ is largely exceeded on the 10th and 11th of August must be admitted. But I think also that the activity of the various positions assigned by Mr. DENNING to the shifting radiant between the 1st and the 10th of August is in excess of the normal amount at the dates assigned. The statistics on this point are not very definite, nor ought the mean of a number of radiants on a given night to be used unless *all* the radiants in that part of the sky are taken into account. It would be easy to prove the shifting by selecting the radiants which agreed with that theory, and rejecting those that did not; but the only legitimate course is to consider all the observed radiants, whether favorable or adverse to the theory. If ten radiants are observed on the same night in the same region of the sky, it is not legitimate to take an average of seven and to leave out the other three. This at least ought not to be done until the existence and nature of the shifting radiant has been placed beyond doubt by an impartial examination of all the available observations in that region; for of course, after proving the existence of a shifting shower, we might adopt a different course from that which is requisite in proving it.

But after the 12th of August Mr. DENNING's catalogue seems to me to be open to objections of the same kind as those which apply to the earlier part of it. The radiants described as belonging to the shifting showers may be equally classed as *Camelopardids*, and there is no evidence that this shower attains its maximum activity at the date assigned to the shifting radiant by Mr. DENNING. Thus a position at $55^{\circ}+57^{\circ}$ on the 15th of August is described as belonging to the shifting *Perseid* radiant, while one from precisely the same point on August 9th and another on August 20-25th are described as belonging to the stationary *Camelopardid* radiant. The former radiant is derived from five meteors, and that on the 9th of August from six, so that there is no reason for regarding August 15th as the date of maxi-

mum activity. A position at $58\frac{1}{2}^{\circ}+59\frac{1}{2}^{\circ}$ on August 15th is referred to the shifting radiant, but the *Camelopardids* give positions at $58^{\circ}+58^{\circ}$ for August 8-13th, at $59^{\circ}+60^{\circ}$ for August 14-19th, and $60^{\circ}+59^{\circ}$ for August 16th. Some at least of these supposed shifting positions appear to be different positions of the same *Camelopardid* radiant, which continues unaltered for at least two months. $50^{\circ}+62^{\circ}$ is given as a *Camelopardid* position for August 3-17th; but within the same limits of date I find among the determinations of the shifting radiant $49^{\circ}+62^{\circ}$ on August 13th, and $54^{\circ}+62^{\circ}$ and $58^{\circ}+62^{\circ}$, both on August 18th, while $55^{\circ}+62^{\circ}$ occurs on August 21st. In none of these instances does there appear to have been any abnormal activity at the time that the shifting radiant is supposed to have reached the particular points referred to, and the evidence of any shifting radiant after August 12th seems to me weak. Evidence worthy of the name is, I think, limited to about ten days out of the forty; and even as regards these ten days, it is not of a very overwhelming character.

I have already noted that it is impossible for an impartial student of Mr. DENNING's catalogue to come to any other conclusion than that the meteors which reach us from the same radiant at different seasons of the year are physically connected. Now there is a permanent, or stationary, radiant just at the point from which the great shower on the 10th and 11th of August emanates. This stationary radiant is active both before and after the great shower. Mr. DENNING (who speaks of these meteors as "*\eta* Perseids") gives one determination at $45^{\circ}+57^{\circ}$ for July 15th-August 2d, another at the same point for July 25-31st, and a third at $43^{\circ}+58^{\circ}$ for July 26-31st. In August I find $43^{\circ}+57^{\circ}$ on the 3d and 4th, $42^{\circ}+57^{\circ}$ on the 5th, $45^{\circ}+57^{\circ}$ on the 6th, $43^{\circ}+56^{\circ}$ on the 13th, $40^{\circ}+59^{\circ}$ on the 21st, and $45^{\circ}+57^{\circ}$ for the period August 24th-September 14th. Some of these are referred to the stationary radiant and others to the shifting one; but the net result appears to be that there is a shower from the same radiant that is active on August 10th and 11th for a month before and after that date. Are we, then, to suppose that this grand shower is physically connected with two meteor-swarms totally unlike in their characteristics, one being fixed, while the other varies from day to day? This is not impossible, if the shower of August 10-11th is really of a composite character,—part belonging to the stationary radiant and part to the shifting radiant,

whose position on these two days is almost the same. When the velocity of meteors can be determined with greater accuracy than at present, we may be able to show that the *Perseids* of August 10 and 11th are divisible into two sets, traveling with different velocities, one belonging to the stationary and the other to the shifting radiant; and by carrying these observations on velocities backwards and forwards, we may be able to analyze the earlier and later composite radiants and to segregate the stationary from the shifting portion of each observed shower. At present, however, we are a long way from any such analysis; and if the existence of the shifting radiant be conceded (though the evidence for it is not as conclusive as one could wish), we are still left in doubt as to the dates on which its activity begins and ceases, and even as to the rate of the shifting. It is very unscientific to base any theory of meteoric radiation on the supposed shifting of the *Perseid* radiant, while overlooking or disregarding the large number of cases in which no shifting whatever has been observed, though the shower sometimes lasts during the whole year. It is indeed the general acceptance of a theory according to which every radiant that continues to be active for more than one night ought to shift its position that renders it worth while to investigate the supposed shifting of the *Perseid* radiant at the length that I have done. Here, if nowhere else, observation is supposed to accord with theory. Is the accordance even in this one instance real? The answer is, at all events, not free from doubt.

For convenience of reference, I may note that the shifting shower is No. XL in Mr. DENNING's catalogue, while the various stationary radiants mixed up with it are Nos. VII, (perhaps VIII), XV, XXI, XXX, XXXII, XXXIX, XLIII (as regards two or three determinations), XLVII, L, LV, and to some extent LVI. The track of the shifting radiant seems to me to lie entirely within the space covered by some one or other of these stationaries, and all of them are active at the date when the shifting radiant is supposed to overlap them as well as before and after that date.

MAXIMA OF *o Ceti* AND OTHER VARIABLES (1899).

BY ROSE O'HALLORAN.

Whether the increase of light in *o Ceti* be caused by collision, internal explosive power, or some other cosmical crisis, it became evident this season that the mysterious agency was withheld from demonstrating its fullest effects. During the maxima that occurred in 1894-95-96, *o Ceti* was distinctly brighter than δ of fourth magnitude; in 1897 it was of fully third magnitude; and in 1898 it formed a conspicuous link in the fragmentary outline named The Whale, being second only to β , now the brightest in the constellation.

The following notes show the rates of increase by which the small maximum of the present year was attained:—

- July 7. Brighter than adjacent star of 7-8 magnitude to the north; dimmer than *71 Ceti* of 6-7 magnitude.
22. In full moonlight as bright as *69 Ceti*.
30. Slightly brighter than *69*. Faint moonlight.
- Aug. 13. Equal to ξ *Piscium*, but redder in tint on a dark sky.
19. Half a magnitude less than δ . Moonlight.
22. One fourth less than δ . Full moonlight.
30. Dimmer than δ . Seen through haze.
- Sept. 5. A half magnitude less than δ on a dark sky.
- Sept. 14. In light of the half-moon it seems brighter than δ . In a few hours when near the meridian after the moon had set, *o Ceti* seemed scarcely equal to δ . It was brighter than ξ *Piscium*, but much fainter than α *Piscium*.
26. Very nearly as bright as δ . Dark moonless sky.
- Oct. 1. A half magnitude less than δ . No moonlight.
8. Slightly brighter than ξ *Piscium*. No moonlight.
13. Equal to ξ *Piscium* in the light of the gibbous moon.
17. Equal to ξ *Piscium*. Nearly full moon 20° distant.
21. Less bright than ξ *Piscium*; brighter than *69 Ceti*. Gibbous moon 30° distant.

U Orionis, a reddish variable of the *o Ceti* type, with a period of about one year, attained a maximum that made it visible with-

out magnifying power on clear dark nights in April last. It is less than half a degree east of X^1 *Orionis*.

Mar. 31. Scarcely as bright as X^2 of 6th magnitude, but brighter than the white star one third of a degree west of X^1 .

April 5, 7, 11, 12. Ditto.

20. Equal to above-mentioned white star. Moonlight.

28. Less than white star.

May 1. Ditto. It has a hazy appearance different from the clear glow at maximum.

5. It is dimmer than the white star, but brighter than the nearest star of 8th magnitude towards the north-west.

A low altitude, sunlight, and cloudy nights hindered further observations until the beginning of October, when it was found to be of 10th magnitude.

Several observations were obtained of the recently found variable *W Lyræ* of irregular period. A maximum was predicted for October 13th, but cloudiness and moonlight prevented satisfactory comparisons, with the exception of the following:—

October 3. The variable is of 11th magnitude.

8. Ditto.

10. Equal to adjacent star of 10th magnitude.

11. It seems slightly decreased.

22. It is fully of 10th magnitude.

SAN FRANCISCO, October 23, 1899.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1900.

BY MALCOLM MCNEILL.

JANUARY.

The Earth is in perihelion on January 1st, 11 P. M., P. S. T.

Mercury is a morning star throughout the month, having passed greatest west elongation on December 25th. On January 1st it rises rather more than an hour and a half before sunrise, and the interval is more than an hour until nearly the middle of

the month; so that it is in fair position for observation. On January 7th it passes close to *Saturn*, not quite 1° to the south.

Venus is an evening star, slowly increasing its apparent distance from the Sun. On January 1st it sets about two hours after sunset, and this interval increases by nearly three quarters of an hour during the month, mainly owing to the rapid northerly motion in Declination of the planet. It moves among the stars from the constellation *Capricornus* nearly through *Aquarius*, 27° eastward and 13° northward.

Mars is too near the Sun to be seen throughout the month, and is in conjunction with it on January 15th, changing from an evening to a morning star. It will not be at all conspicuous until nearly the close of the year, as it approaches its opposition in the spring of 1901.

Jupiter rises about three hours before sunrise on January 1st, and four and a half hours before on January 31st. It is in the constellation *Scorpio*, and moves about 6° eastward during the month. On the morning of January 4th it makes a very close approach to the third-magnitude star β *Scorpii*, the planet passing about $13'$ south of the star. The time of nearest approach is about sunrise on the Pacific Coast.

Saturn passed conjunction with the Sun on December 17th and by the beginning of the month is just beginning to be visible as a morning star. By the end of the month it rises two and one half hours before sunrise. It is in the western part of the constellation *Sagittarius*, and moves about 4° eastward during the month. On the morning of January 28th the Moon passes just to the north of the planet, and there will be an occultation for the region south and east of the United States.

Uranus rises from two to four hours before sunrise. It is about 20° west of *Saturn* in the constellation *Scorpio*, and moves slowly eastward.

Neptune is moving slowly westward near the border line of the constellations *Taurus* and *Gemini*.

FEBRUARY.

Mercury is a morning star at the beginning of the month, too near the Sun to be seen. It passes superior conjunction on February 9th, becoming an evening star, and moves away from the Sun, being well out toward east elongation by the close of the month, and setting nearly an hour and a half after sunset. It can

probably be seen on a clear evening during the last week of the month.

Venus is an evening star, still slowly increasing its distance from the Sun; and on account of its relatively greater northward motion in Declination increasing its interval of visibility after sunset in still greater measure, until it is more than three hours at the close of the month. On the afternoon of February 1st it is $0^{\circ} 13'$ south of the fourth-magnitude ϕ *Aquarii*, and it moves rapidly eastward 30° and northward 14° from *Aquarius* through *Pisces*.

Mars is a morning star, but remains quite close to the Sun, its eastward motion among the stars being only a very little less than that of the Sun.

Jupiter rises about an hour and a half earlier than during January, and by the end of the month it comes up at a little after 1 A. M. It is in quadrature with the Sun on February 28th. It is in the constellation *Scorpio*, and moves about 3° eastward among the stars.

Saturn is also a morning star, rising two hours later than *Jupiter*, and moves eastward among the stars at about the same rate, 3° during the month. The Moon approaches the planet again very closely on the afternoon of February 24th, but the phenomenon occurs during daylight in the United States.

Uranus is in the neighborhood of *Jupiter*, 5° east and $1^{\circ} 30'$ south, in the constellation *Scorpio*. It moves about 1° eastward during the month, and at the end is only about 3° east of *Jupiter*.

Neptune remains in about the same position on the border of the constellations *Taurus* and *Gemini*.

JANUARY-FEBRUARY, 1900.

PHASES OF THE MOON, P. S. T.

			H.	M.	
New Moon,	January	1,	5	52	A.M.
First Quarter,	January	7,	9	40	P.M.
Full Moon,	January	15,	11	8	A.M.
Last Quarter,	January	23,	3	53	P.M.
New Moon,	January	30,	5	23	P.M.
First Quarter,	February	6,	8	23	A.M.
Full Moon,	February	14,	5	50	A.M.
Last Quarter,	February	22,	8	44	A.M.
New Moon.	February	29,	3	25	A.M.

THE SUN.

1900		R. A.	Declination.	Rises.	Transits.	Sets.
		H. M.	°	H. M.	H. M.	H. M.
Jan.	1,	18 46	— 23 1	7 27 A.M.	12 4 P.M.	4 41 P.M.
	11,	19 30	— 21 50	7 26	12 8	4 50
	21,	20 13	— 19 56	7 22	12 11	5 0
Feb.	1,	20 59	— 17 8	7 13	12 14	5 15
	11,	21 39	— 14 4	7 2	12 14	5 26
	21,	22 18	— 10 37	6 50	12 14	5 38
Mar.	1,	22 48	— 7 38	6 38	12 13 P.M.	5 48

MERCURY.

Jan.	1,	17 15	— 22 0	5 52 A.M.	10 33 A.M.	3 14 P.M.
	11,	18 15	— 23 41	6 13	10 53	3 33
	21,	19 21	— 23 30	6 44	11 19	3 54
Feb.	1,	20 37	— 20 40	7 6	11 52	4 38
	11,	21 46	— 15 31	7 16	12 22 P.M.	5 28
	21,	22 56	— 8 3	7 19	12 52	6 25
Mar.	1,	23 46	— 1 9	7 15	1 11	7 7

VENUS.

Jan.	1,	20 39	— 20 10	9 9 A.M.	1 57 P.M.	6 45 P.M.
	11,	21 30	— 16 37	9 1	2 7	7 13
	21,	22 17	— 12 19	8 58	2 16	7 34
Feb.	1,	23 8	— 6 58	8 47	2 23	7 59
	11,	23 52	— 1 48	8 34	2 28	8 22
	21,	0 38	+ 3 26	8 21	2 32	8 43
Mar.	1,	1 10	+ 7 34	8 9	2 35	9 1

MARS.

Jan.	1,	19 2	— 23 37	7 46 A.M.	12 20 P.M.	4 54 P.M.
	11,	19 36	— 22 37	7 35	12 14	4 53
	21,	20 9	— 21 12	7 23	12 7	4 51
Feb.	1,	20 44	— 19 12	7 8	noon	4 52
	11,	21 16	— 17 0	6 51	11 52 A.M.	4 53
	21,	21 47	— 14 30	6 33	11 43	4 53
Mar.	1,	22 12	— 12 20	6 18	11 36	4 54

JUPITER.

Jan.	1,	15 57	— 19 37	4 24 A.M.	9 15 A.M.	2 6 P.M.
Feb.	1,	16 20	— 20 36	2 48	7 35	12 22
Mar.	1,	16 33	— 21 5	1 14	5 59	10 44 A.M.

SATURN.

Jan.	1,	17 50	— 22 26	6 29 A.M.	11 8 A.M.	3 47 P.M.
Feb.	1,	18 5	— 22 27	4 41	9 20	1 59
Mar.	1,	18 15	— 22 24	3 1	7 40	12 19

URANUS.

I,	16 34	— 21 55	5 11 A.M.	9 52 A.M.	2 33 P.M.
II,	16 40	— 22 8	3 16	7 56	12 36
III,	16 44	— 22 14	1 29	6 9	10 49 A.M.

NEPTUNE.

I,	5 39	+ 22 4	3 35 P.M.	10 54 P.M.	6 13 A.M.
II,	5 36	+ 22 3	1 31	8 50	4 9
III,	5 35	+ 22 4	11 40 A.M.	6 59	2 18

ECLIPSES OF JUPITER'S SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

	H.	M.			H.	M.
D, Jan. 4,	3	24	A.M.	I, D, Feb. 3,	5	37 A.M.
D, 11,	5	28		I, D, 5,	12	6
D, 12,	3	32		II, D, 6,	12	27
D, 19,	6	5		I, D, 12,	1	59
D, 20,	1	50		II, D, 13,	3	0
R, 23,	1	19		II, R, 13,	5	18
D, 27,	3	43		I, D, 19,	3	52
D, 30,	3	47		II, D, 20,	5	32
R, 30,	5	17		I, D, 26,	5	46
				I, D, 28,	12	14



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

STARS WITH VARIABLE VELOCITIES IN THE LINE OF SIGHT.

The eight stars following should be added to the seven previously announced by me in these *Publications* as having variable velocities in the line of sight.

ε Librae.

The variable velocity of this star, detected several months ago, is indicated by the following results:—

1899, April	13	—	8 km.
May	10	+	12.2
	15	+	7.5
June	12	—	7.5
	14	—	7.0
	26	—	11.2
July	13	—	10.8

The period is undetermined, but it seems to exceed three months.

h Draconis.

The velocities obtained for this star are:—

1899, June	26	—	26 ^{km.}
July	11	—	36
	16	—	32
	24	—	16

The period remains undetermined.

λ Andromedæ.

The velocities obtained up to date are:—

1897, Nov.	16	+	16 ^{km.}
1898, Oct.	18	—	2
	26	+	13
1899, July	5	+	15
	11	+	3
	12	+	2
	16	+	1
	24	+	14

* Lick Astronomical Department of the University of California.

These observations are apparently satisfied by a period of about twenty days.

ε Ursæ Minoris.

The velocities observed for this star are as below:—

1897, May	5	+ 3 ^{km.}
	27	— 35
July	21	— 10
Aug.	4	+ 9
1899, July	31	— 40

The period remains undetermined.

ω Draconis.

The velocity of this star in the line of sight varies rapidly.

Four spectrograms give the following results:—

1899, July	25	+ 18 ^{km.}
Aug.	8	— 45
	9	— 12
	29	— 53

β Capricorni.

For this star we have the following observed velocities:—

1898, Aug.	15	— 5 ^{km.}
1899, May	15	— 42.9
	29	— 44.6
	29	— 44.4*
June	8	— 42.4
	14	— 42.4
	26	— 41.1
July	12	— 40.3
	24	— 39.1
Aug.	12	— 37.8
	15	— 38.6†
Sept.	4	— 35.2
	10	— 34.5
	25	— 33.0†
	26	— 33.8

The period remains undetermined, but is evidently long.

α Aurigæ (Capella).

The spectrum of this star is composite. The component whose spectrum is of the solar type furnished the following velocities with reference to the solar system:—

* Measures of the same plate by Mr. WRIGHT. † Measures by Mr. WRIGHT.

Publications of the

1896, Aug. 31	+ 34 ^{km.}
Sept. 16	+ 54
Oct. 3	+ 49
5	+ 44
Nov. 12	+ 4
1897, Feb. 24	+ 3

On the first photograph the spectrum is of essentially normal solar type; on the others it is unmistakably different. There appears to be a second component whose spectrum contains the *H γ* line and the rather prominent iron lines. On the plates of September 16th, October 3d, and October 5th, these lines are shifted toward the violet with reference to the solar-type spectrum; and in the spectra of November 12th and February 24th, they are shifted toward the red.

v Sagittarii.

To the present time we have secured six spectrograms of this star which give the following velocities:—

1896, July 1	— 3 ^{km.}
1899, Aug. 23	— 31
28	— 28
Sept. 5	— 18
12	+ 2
19	+ 10

These measures may be uncertain to the extent of several kilometers, on account of the peculiar and difficult character of the spectrum.

Acknowledgments are due to Mr. WRIGHT for his skillful assistance in the observations. W. W. CAMPBELL.

November, 1899.

SPECTROSCOPIC BINARY STARS.

In No. 60 of these *Publications*, I gave a short account of the spectroscopic binary stars known to exist before January, 1898, dividing them into three classes—(1) those known by the periodic partial eclipse of the bright star by a relatively dark companion, that is, the *Algol*-type variables; (2) those known by the periodic doubling of the lines in the star's spectrum, like β *Aurigæ*; and (3) those known by the shifting of the spectral lines alternately toward the red and the violet ends of the spectrum, as compared with the corresponding lines in the artificial spectrum of hydrogen or iron. At that time, the stars of

the first class, or *Algol*-type variables, were by far the most numerous, numbering fourteen certainly, and sixteen probably, as compared with five of the second class and only two (or four, if we include δ *Cephei* and η *Aquilæ*) of the third class.

In the past two years so many stars have been added to the list of known spectroscopic binaries that it seems advisable to summarize briefly these additions, especially as the relative numbers in the three classes named have been decidedly changed.

A notable addition to the list of *Algol*-type stars has been made in the star DM $+ 45^{\circ} 3062$, discovered as variable by Madame CERASKI in 1899, in her study of photographic plates taken by M. BLAJKO, assistant in the observatory at Moscow. This discovery has been verified by numerous observers and the period of $4^d.572$ determined with accuracy. The remarkable feature in this star is the range of variability — the maximum brightness being 8.6 magnitude, the minimum only 11.5.

Two other *Algol*-type variables have been announced — DM $+ 12^{\circ} 3557$, a star having a period of only $21^h 21^m$, and a range of magnitude from 7.0 to 7.5, by SAWYER in 1898; and CPD $- 41^{\circ} 1681$, a star ranging from 9.5 magnitude to 10.7 in 12.906 days, by INNES in the present year. So far as I know, these have not been verified by other observers.

No additions have been made to the second class of spectroscopic binaries, if we except *Capella* (α *Aurigæ*), whose binary character was discovered by CAMPBELL, by the shifting of the spectral lines. Subsequent examination has proved the spectrum to be composite, and some of the lines appear double at regular intervals.

It is to the binaries of the third class — systems consisting of a bright star and a relatively dark companion whose orbital plane is so inclined to the line of sight that no eclipse occurs, and which are hence known only by the periodic shifting of the lines of the bright star's spectrum — that the most numerous and important additions have been made. Of this class but two were known previous to 1898, α *Virginis* and α *Geminorum*. In the past two years BELOPOLSKY has added two, and CAMPBELL fourteen, in addition to the independent discovery of ξ *Geminorum*,* which is credited to BELOPOLSKY.

* This star, with δ *Cephei* and η *Aquilæ*, should perhaps be classed separately, having been supposed to be binary systems from the regular character of their light variations long before the spectroscope proved their variable velocity in the line of sight.

This list now stands as follows:—

STAR.	DISCOVERER AND DATE.	PERIOD.
α <i>Virginis</i>	VOGEL, 1890	4.0134 days.
δ <i>Cephei</i>	BELOPOLSKY, 1894	5 $\frac{1}{3}$ days.
η <i>Aquilæ</i>	" 1895	7 $\frac{1}{6}$ days.
α' <i>Geminorum</i>	" 1896	2.91 days.
η <i>Pegasi</i>	CAMPBELL, 1898	2 $\frac{1}{4}$ years.
χ <i>Draconis</i>	" "	9 $\frac{1}{3}$ months.
$\circ$ <i>Leonis</i>	" "	14 $\frac{1}{2}$ days.
ζ <i>Geminorum</i>	BELOPOLSKY* 1898	10 $\frac{1}{6}$ days.
θ <i>Ursæ Majoris</i>	" 1899	5 to 7 days.
i <i>Pegasi</i>	CAMPBELL, 1899	10 + days.
θ <i>Draconis</i>	" "	9 + days.
ϵ <i>Libræ</i>	" "	Unknown — several months.
β <i>Capricorni</i>	" "	Unknown — long.
h <i>Draconis</i>	" "	Unknown.
λ <i>Andromedæ</i>	" "	20 days $\pm$
ϵ <i>Ursæ Minoris</i>	" "	Several weeks.
ω <i>Draconis</i>	" "	Unknown.
α <i>Ursæ Minoris</i> (<i>Polaris</i>)	" "	3 ^d 23 ^h $\pm$
α <i>Aurigæ</i> (<i>Capella</i>)	" "	3 $\frac{1}{2}$ months.
v <i>Sagittarii</i>	" "	Several weeks.

Of the spectroscopic binaries known before 1898, only one had a period exceeding ten days, viz.: ζ *Ursæ Majoris*, which completes a revolution in about fifty-two days. But of those found recently, several have periods of a number of months, and one — η *Pegasi* — a period of two and one-quarter years. There is, therefore, no longer a gap in this respect between the spectroscopic binaries and those known visually. It is also of interest to note that the proportion of known spectroscopic binaries to the

* In January, 1899, Professor CAMPBELL found that the velocity of ζ *Geminorum* in the line of sight was variable, and announced his discovery in the *Astrophysical Journal*, (vol. IX, p. 86). This announcement called forth a note by Professor BELOPOLSKY in *Astronomische Nachrichten* (3565), in which he stated that he had anticipated this discovery by a year, and had made a statement concerning it at a meeting of the Russian Astronomical Society in February, 1898. CAMPBELL'S discovery was, however, entirely independent, as no notice of BELOPOLSKY'S investigations had been published, so far as known here.

stars whose velocities in the line of sight have been well determined indicates that these systems are at least as numerous as visual binaries.

R. G. AITKEN.

November, 1899.

COMET *c*, 1899 (GIACOBINI).

This comet was discovered by M. GIACOBINI, at Nice, on September 29th, 7^h 30^m Gr. M. T., in α 16^h 26^m 32^s, δ — 5° 10'. It was moving slowly east and north. From the Königsberg observation of October 1st and my own of October 7th and 16th, I have computed the following system of parabolic elements:—

$$\begin{array}{rcl} T = & 1899 \text{ Sept. } 15.0430 \text{ G. M. T.} \\ \omega = & 10^{\circ} 51' 55''.9 \\ \Omega = & 272 \quad 12 \quad 32.1 \\ i = & 76 \quad 55 \quad 18.8 \end{array} \left. \vphantom{\begin{array}{l} T \\ \omega \\ \Omega \\ i \end{array}} \right\} 1899.0$$

$$\log q = 0.251754$$

These elements gave residuals for the middle place as follows:

$$\begin{array}{rcl} \text{Obs. - Comp: } \Delta \lambda' \cos \beta' & + & 8''.9 \\ & \Delta \beta' & + 1.8 \end{array}$$

On December 1st the comet's position will be

$$\alpha \ 18^h \ 6^m \quad \delta \ + \ 12^{\circ} \ 32'$$

It will still continue to move northeast.

At the time of discovery the comet was faint, being estimated at 10½ or 11 magnitude on October 2d. It was 1' in diameter, and had a faint nucleus. On December 1st its theoretical brightness will be 0.47, that at discovery. It has faded gradually. The last observation was secured on November 23d, when it was estimated at thirteenth magnitude. On that date the deviation from the above orbit was

$$\begin{array}{rcl} \text{Obs. - Comp: } \alpha & - & 3'' \\ & \delta & - 0'.4 \end{array}$$

This is the third comet discovered by M. GIACOBINI.

Mt. HAMILTON, November 28, 1899.

C. D. PERRINE.

TEMPEL'S, COMET.

This comet was last observed on November 22d. It was then about ½' in diameter and of fourteenth magnitude.

HOLMES'S COMET.

The last observation of this comet was secured on November 6th. It was estimated as fifteenth magnitude.

Mt. HAMILTON, November 28, 1899.

C. D. PERRINE.

OBSERVATIONS OF THE *LEONIDS* AT THE LICK OBSERVATORY.

During the whole period of the apparition of the *Leonids*, stormy or cloudy weather prevailed at Mt. Hamilton, so that no observations of value could be made. The sky was, however, seen occasionally. On November 13th (astronomical reckoning) the sky cleared suddenly at 16^h 30^m, and a watch was kept until dawn. Ten *Leonids* were counted in one hour. Two of these were fine meteors, brighter than the average first-magnitude star. On November 15th, after 12^h, the sky was seen at intervals through rifts in the dense fog which surrounded the summit of the mountain. One or two meteors, apparently *Leonids*, were seen, but it was evident that nothing like a considerable shower was in progress. On the succeeding nights there were dense fogs and heavy rains.

From these few observations, and others made at more favored places in the State, it would seem that the display of meteors in this part of the world was no greater in 1899 than in an ordinary year.

J. E. K.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, Mass., Oct. 2, 1899.

(Received 7:15 P.M.)

To Professor J. E. KEELER, Lick Observatory:

Kiel cables that Comet *c** was observed by COHN at Königsberg on Oct. 1.2767 G. M. T.; in R. A. 16^h 31^m 0^s.7; Decl. — 4° 39' 50".

(Signed) E. C. PICKERING.

Lick Observatory, Oct. 3, 1899.

To Harvard College Observatory:)
To Students' Observatory, Berkeley: { (Sent 10:20 A.M.)

Comet Giacobini was observed by PERRINE on Oct. 2.6758 G. M. T.; in R. A. 16^h 32^m 59^s.7; Decl. — 4° 12' 18".

Lick Observatory, Oct. 4, 1899.

To Students' Observatory, Berkeley: (Sent 10:25 A.M.)

Comet Giacobini was observed by PERRINE on Oct. 3.6378 G. M. T.; in R. A. 16^h 34^m 22^s.1; Decl. — 3° 53' 35".

*For some reason, the telegram announcing M. GIACOBINI'S discovery did not reach the Lick Observatory. The first information of the comet's existence was obtained from the notice in the daily papers.

Lick Observatory, Oct. 4, 1899.
 To Students' Observatory, Berkeley: (Sent 9:32 P.M.)
 Comet Giacobini was observed by PERRINE on Oct. 4.6292
 G. M. T.; in R. A. $16^h 35^m 46^s.7$; Decl. $- 3^\circ 34' 40''$.

Lick Observatory, Oct. 21, 1899.
 To Harvard College Observatory: (Sent 12:11 P.M.)
 Elements and ephemeris [here omitted] of Comet ϵ were com-
 puted by PERRINE as follows:—

$$\begin{array}{rcl} T = \text{Sept. } 15.04 & \text{G. M. T.} & \\ \omega = 10^\circ 52' & & \\ \Omega = 272 \quad 13 & \left. \vphantom{\begin{array}{l} \omega \\ \Omega \end{array}} \right\} \text{Equinox of 1899.0} & \\ i = 76 \quad 55 & & \\ q = 1.7854 & & \end{array}$$

ERRATA IN STAR CATALOGUES.

At various times I have noted the following errata in star catalogues:—

WEISSE'S BESSEL'S ZONES $+ 15^\circ$ to $- 15^\circ$:—
 $23^h 964$. For $- 0^\circ 11' 4''.8$, read $- 0^\circ 10' 4''.8$.

ARGELANDER'S *Durchmusterung*: (Bonner Beob. III).

Heading, page 169. For $+ 6^\circ$, read $+ 7^\circ$.

DM $+ 10^\circ 26$ is indicated as given in Bonner Beob. VI.

It is DM $+ 10^\circ 27$ that is given in this volume.

SCHUR'S Göttingen Catalogue:—

No. 16. For DM $+ 9^\circ 38$, read $+ 9^\circ 8$.
 5602 . " $+ 6^\circ 5757$ " $- 6^\circ 5757$
 2121 . " 7^h " 8^h

BALL'S Vienna Ottakring Zones:—

Zone 74, DM $- 6^\circ 5600$. For $20^h 44^m 18^s.78$, read $20^h 45^m 18^s.78$.
 Zones 4 and 110. " $- 6^\circ 1554$, " $- 6^\circ 1564$
 Zones 110 and 232. " $- 6^\circ 1560$, " $- 6^\circ 1570$

ROMBERG'S Pulkowa Catalogue:—

No. 1803. For $+ 32^\circ$ etc., read 33° etc.
 No. 4120. " $0^\circ 325$, " $0^\circ 525$.
 No. 4617. " $2^\circ 2707$, " $2^\circ 2704$.

DEICHMULLER'S Bonn A. G. Catalogue:—

No. 202. The proper motion in Right Ascension of this
 star is given $+ 0^s.022$. In AUWERS'S BRADLEY it is
 given $+ 0^s.0022$. The latter value is also given by
 ROMBERG, probably taken from AUWERS.

W. J. HUSSEY.

MT. HAMILTON, November 24, 1899.

GENERAL NOTES.

The Committee on Publication has decided to conduct a new department in the *Publications* under the title given above. Many notes of a general character have appeared in the Notices from the Lick Observatory, but hereafter notices in that department will be confined to accounts or results of investigations being carried on in that institution. Members and friends of the Society are invited to aid the committee in carrying out the work of this new department. Communications of general interest will be gladly received and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Through the courtesy of Professor A. O. LEUSCHNER, of the University of California, we are able to reproduce as our frontispiece, a photograph of the new observatory at Potsdam. The building contains the new refractor, the object-glasses of which were cast by SCHOTT in Jena, and ground by C. A. STEINHEIL SONS in Munich. The photographic objective has an aperture of 80^{cm} (31.5 inches) and focal length of 12 meters, while the visual has an aperture of 50^{cm} and focal length of 12½ meters. The mounting was made by A. REPSOLD & SONS. The instrument is to be used principally for the determination of radial velocities of the stars. The dedication of the new observatory was held, amid elaborate ceremonies attended by the Emperor, on the 26th of August of the present year.

The *Scientific American* for November 4, 1899, contains an illustrated article on the great telescope being constructed for the Paris Exposition. The objective is 4.1 feet in diameter, and weighs 1,295 pounds. A photographic objective of the same size has also been made. The discs were cast by MANTOIS and the grinding was done by GAUTIER. The telescope tube, 197 feet in length, is to be mounted in a stationary horizontal position, and the light is to be reflected into the objective by means of a huge plane-mirror to be driven by clockwork. The mirror is 6.56 feet in diameter, 10.63 inches thick, and weighs 7,920 pounds. The glass was cast at the Jenmont Works, and one of sufficient size was obtained only after several trials. The grinding and polishing consumed ten months. The operation is a most delicate one on account of the heat produced in the process. The mirror and its mounting weigh 99,000 pounds, and a weight of 220 pounds is necessary to run the clock.

The number of students in the astronomical courses at the University of California has increased so largely that it has become necessary to build an addition to the Students' Observatory. This

will be a lecture-room, with a rising floor and a seating capacity of 135. The total enrollment in the astronomical courses this semester is 137, representing 109 different students, of whom eight are graduate students.

In a short article on the transit-micrometer, in No. 470 of the *Astronomical Journal*, Mr. A. S. FLINT, of the Washburn Observatory, remarks as follows: "The performance of this transit-micrometer in general has been very satisfactory. As shown by the experience of European observers, this device reduces the differences of personal equation between observers to a small fraction of their value under the old method, and it is expected that it will also avoid practically variations of personal equation in the same observer." It is to be hoped that this simple and practical device may soon be universally adopted for meridian-circle work; for there is scarcely any longer a doubt that it almost eliminates the personal equation, which has always been such a troublesome factor in meridian-circle observations.

In the November number of *Popular Astronomy*, Professor FRANK H. BIGELOW contributes an article under the title, "Result of the Observations of the Weather Bureau for the Probable Cloudiness of the Sky along the Path of the Total Eclipse of the Sun, May 28, 1900." Observations of the general cloudiness and clouds in the neighborhood of the Sun were carried out by the Weather Bureau at various stations along the path of totality, from May 15th to June 15th, during the years 1897, 1898, and 1899. The result of the observations is that the cloudiness is least in Georgia and Eastern Alabama, increasing in either direction, and greater on the Atlantic Coast than in the region of the Gulf of Mexico. A detailed statement of the conditions existing at the various cities and villages is also given.

The article closes with the following statement: "The Chief of the Weather Bureau sent a circular letter to a number of towns located near the central line, requesting replies to several questions of interest to astronomers, in order that such practical information might be furnished them regarding the locality as would assist in deciding upon the best sites. The questions concern the latitude, longitude, altitude, population, accommodations, railroads, topography, eastern horizon, wind, and drift of smoke, and suggestions regarding good sites accessible to heavy baggage. The replies of thirty-seven places are summarized in

the report of the Weather Bureau for 1899, to which those interested are referred. The astronomers of the United States and foreign countries will appreciate the assistance which so many volunteer observers have cheerfully rendered in making this survey as complete as possible."

The library of the Society has recently received a copy of the *Indian Eclipse, 1898*, being a report of the expeditions organized by the British Astronomical Association to observe the total solar eclipse of 1898, January 22d, edited by E. WALTER MAUNDER, F. R. A. S. The book is profusely illustrated with cuts of superior excellence. Several reproductions of photographs of the corona and spectra are given, but the majority of the cuts are of observing-stations, instruments, drawings of corona, and a variety of Indian scenes. Among the cuts are two of Professor CAMPBELL's station at Jeur. "The Lick camp was conspicuous by the long forty-foot telescope, which, with its end planted in a pit some eight feet deep, shot up into the air above the tree-tops. A marked feature, too, was the Stars and Stripes, which, supported by the Union Jack, very appropriately floated above the *chupper* roof of their banqueting-hall. It was a sign of good feeling and comradeship which characterized the whole intercourse between the camps. In the shadow of the gigantic tube, and looking quite dwarfed beside it, were the Professor's other instruments for spectrum photographs and smaller coronal images. The great telescope gave a disc of nearly five inches in diameter, the largest obtained in the camp. But it is interesting to note that the astronomers were not too proud to use the humbler and smaller every-day camera for snap-shots—all were pressed into service." A description is given also of Professor BURCKHALTER's equipment. On page 50 is the following: "Our American friends rather astonished the natives, for there was nothing they could not do, and did not do, with their own hands—from driving a screw or sawing a plank to the most delicate adjustments of their instruments. Visitors might have passed them by at their work in looking for more presentable professors. Having brought their own tools and implements, they were certainly independent of the village carpenter." It is barely possible also that the natives were not the only surprised ones.

In the last chapter a summary of results and suggestions for future work are given.

SUMMARY OF RESULTS.

1. The spectrum of the "Flash" has been successfully photographed on five plates.
2. A new region of the "Flash" spectrum has been explored and mapped.
3. The bright line spectrum of hydrogen has been followed in the chromosphere to the thirtieth point of the series, and the wave-lengths are shown to agree closely with BALMER's formula.
4. The correction to the received wave-length of the "coronium" line detected by Mr. FOWLER has been confirmed.
5. The distribution of "coronium" in the corona has been examined.
6. Several drawings of the corona as seen by the unaided eye have been made.
7. The variation of the form of the corona with the sun-spot cycle has been further illustrated.
8. Twenty-eight photographs of the corona have been taken.
9. These include several showing the coronal rays to a greater distance from the Sun than they have ever been photographed before.
10. And cast fresh light upon their structure.
11. Beside restoring the credit of many old drawings of eclipses, which had been supposed untrustworthy because of their want of resemblance to the photographs.
12. The wide range of exposures employed furnishes a most valuable guide as to the exposures to be employed in future eclipses.
13. The corona has been definitely photographed during the partial phase.
14. In several different and independent ways a measure has been obtained of the total illumination given by the corona.

The suggestions for work in future eclipses are given under the following headings: Drawings of the Corona; Spectroscopic Observations; Proper Exposures for Photographs of the Corona; Photographs during the Partial Phase; Determination of the Brightness of the Corona.

The suggestions there made are well worth the consideration of persons who expect to observe the eclipse next May.

The Board of Visitors to the United States Naval Observatory appointed by Secretary LONG last spring met at the Observatory in Washington on June 30, 1899, and submitted their report on October 2d. The members of the Board were: the Hon. WILLIAM E. CHANDLER, the Hon. ALSTON G. DAYTON, and Professors EDWARD C. PICKERING, GEORGE C. COMSTOCK, and GEORGE E. HALE.

The report is divided into eight sections, as follows:—

- I. Recommendation of the Board of Visitors.
- II. Circumstances leading to the appointment of the Board of Visitors.
- III. Cost of the Observatory.
- IV. Comparison with other observatories.
- V. Present condition and methods of observatory work and the delay in printing its results.
- VI. Historical sketch of the Observatory.
- VII. Minutes of the proceedings of the Board of Visitors.
- VIII. Appendix.

Section I was printed in full in the November numbers of *Popular Astronomy* and the *Astrophysical Journal*. Its essential points are given in the following extracts. Sections II, III, and IV, which we print below, were kindly communicated by one of the members of the Board of Visitors.

RECOMMENDATIONS OF THE BOARD OF VISITORS.

... "The Naval Observatory, which was originally established as a scientific bureau, auxiliary to the needs of the naval service, has become through half a century of growth, and through the expenditure of large sums of money, as authorized by law, an astronomical observatory of the first rank in respect of buildings, instruments, and equipment. But by far the larger and more valuable part of its equipment has little or no reference to any direct requirement of the naval service, and its existence can be justified only on the ground that Congress has intended to establish and maintain a national astronomical observatory. Under these changed circumstances its continued connection with the Navy Department has seemed to many of those whose views have been submitted to the Board of Visitors, illogical and undesirable. In view, however, of the absence of a national university, a department of science and industries, or other department or bureau of the Government especially suited to the conduct of such scientific work, and in view of the diversity of opinion among American astronomers upon the question to which existing department the observatory could be wisely transferred, we believe it to be inexpedient for us at the present time to further consider the subject of such transfer. . . .

"If the observatory, as a shore station charged with the performance of certain functions assumed to have a relation to the navy, is to continue under the command of a line officer, we recommend that the astronomical staff of the Naval Observatory shall consist of an astronomical director, four astronomers, three assistant astronomers, and such computers and other minor officers as may be provided by law. The astronomical director and astronomers, whether professors of mathematics or taken from civil life, and the assistant astronomers, should be appointed by the President, by and with the advice and consent of the Senate, to hold their offices until their successors are appointed.

"The Nautical Almanac office, which was formerly a distinct bureau, is now administered by departmental regulation as a part of the Naval

Observatory, and it appears from the evidence submitted to the Board of Visitors, that a successful administration of the observatory is much impeded by reason of imposing upon its astronomical director the duties of director of the Nautical Almanac. Each of these offices furnish abundant employment for the entire time of an able astronomer, and we therefore recommend that there shall be a director of the Nautical Almanac appointed by the President, by and with the advice and consent of the Senate, to hold office until his successor is appointed. . . .

"There shall be appointed by the President, from persons not officers of the United States, a board of nine visitors to the Naval Observatory, six to be astronomers of high professional standing, and three to be eminent citizens of the United States. Appointments to this board shall be made for periods of three years, but provisions shall be made by initial appointments for shorter terms, so that two astronomers and one member of the board not an astronomer shall retire in each year. Members of this board shall serve without compensation, but the Secretary of the Navy shall pay the actual expenses necessarily incurred by members of the board in the discharge of such duties as are assigned them by the Secretary of the Navy, or are otherwise imposed upon them. . . .

"If astronomers are appointed to the Naval Observatory from civil life to succeed retiring professors of mathematics, the salaries provided should be sufficient, as recommended by you in that report of 1897, 'to make up for the refusal to them of the privilege of retirement, and also to secure men of high scientific attainments adequate to the demands of one of the most capable observatories of the world.' To secure the services of the ablest astronomers the salaries provided should be slightly larger than those paid in the higher class of university observatories, and account should be taken of the fact that university vacations are much longer than leaves of absence from public service. The Board of Visitors recommends the following as a schedule of salaries which could be expected to attract astronomers of the class desired: Astronomical director, \$6,000; director of Nautical Almanac, \$5,000; first astronomer, \$4,000; second astronomer, \$3,600; third astronomer, \$3,200; fourth astronomer, \$2,800; first assistant astronomer, \$2,400; second assistant astronomer, \$2,200; third assistant astronomer, \$2,000.

"The experience of every great observatory shows that the efficiency of its staff is materially increased by the provision of quarters near the observing-room for those persons who are engaged in work by night, and we recommend that there should be quarters provided upon the observatory grounds for all members of the astronomical staff regularly assigned to night work.

"In concluding its recommendations, the Board of Visitors wishes earnestly to urge upon your consideration the necessity of making a success of the movement which you have begun in order to improve the condition of the Naval Observatory and to make its administration satisfactory to the great body of astronomers, of the country and to the public.

"Some of our recommendations, if they meet your approval, can be carried into effect by departmental action; but the changes which we

regard as vital can only be obtained through legislation by Congress. If such legislation is withheld, the continuance of present conditions is sure to result in a renewed, persistent, and possibly acrimonious demand for the removal of the observatory from naval command. If, however, the legislation is enacted, and the improved system is given a fair trial, unquestionably much improvement will result, and it is not improbable that the observatory will attain and hold that high standing in the scientific world which should be required of such an institution." . . .

REPORT OF COMMITTEE OF ASTROPHYSICAL CONFERENCE.

"At the Harvard Astronomical Conference, held in Cambridge, on August 18, 1898, the undersigned were appointed a committee to consider what changes, if any, were advisable in the organization of the United States Naval Observatory. A circular was sent to the principal astronomers in the United States, asking six questions regarding means of increasing its astronomical efficiency. Sixty-one replies were received, with the following approximate results, doubtful answers being counted as one half:

1. A change in organization is recommended. 51 to 2.
2. The entire direction of the observatory should be intrusted to an astronomer. 54 to 3.
3. Transfer of the observatory to some other department of the Government. 19 to 19.
4. Separation from the observatory of various branches, such as the testing of nautical instruments. 26 to 24.
5. Tenure of office and advancement should depend on scientific efficiency, rather than upon age or length of service. 50 to 2.
6. A Visiting Committee should be appointed. 43 to 6.

"It therefore appears that opinion is nearly equally divided whether a portion or the whole of the observatory should be transferred to some other department, but is nearly unanimous in favor of changing the present organization, of intrusting the entire direction to an astronomer, of making advancement depend on scientific efficiency, and of appointing a Visiting Committee. To be efficient this committee should have power to act, and should consist of experts who would serve without pay.

"In March, 1899, the Secretary of the Navy decided to create the present Board of Visitors to the Naval Observatory.

"**COST OF OBSERVATORY.**—The financial condition of the observatory is shown in the Appendix, Exhibit H, which gives the total cost of grounds and buildings to July 1, 1899, to be \$473,200; estimated value of the grounds, buildings, and instruments, \$856,547.35; annual appropriations for the year ending June 30, 1899, \$51,160; and annual appropriations for grounds and roads for the same year, \$11,200. To the current expenses of \$51,000 should be added several items, really paid for by the Government but not included in the above appropriations. Their amounts will vary from year to year, and can only be estimated approximately. They include,—

"First, the salaries of the Superintendent and other line officers detailed for duty at the observatory; estimated amount, \$6,000.

"Second, salaries of professors of mathematics. There are now five of these at the observatory besides one temporarily ordered to the Bureau of Yards and Docks; estimated amount, \$15,000.

"Third, retired pay of professors of mathematics who served as astronomers; estimated amount, \$10,000.

"Fourth, cost of printing publications; estimated amount, \$3,000.

"According to these estimates, the total annual cost to the Government exceeds \$85,000, not including expenditures for the Nautical Almanac. In any plan for reorganization the sum of \$85,000 annually should therefore be assumed as that available, unless it is the intention of Congress to reduce the expenses rather than to increase the amount of useful work accomplished.

"COMPARISON WITH OTHER OBSERVATORIES.—From a comparison of the resources of the Naval Observatory with those of the principal observatories of the world, it appears that the observatories having the largest annual incomes are as follows: Naval Observatory, \$85,000; Paris, \$53,000; Greenwich, \$49,000; Harvard, \$46,000; Pulkowa, \$46,000; Cape of Good Hope, \$33,000. The resources of some of the richest private observatories are not published, but it is probable that none of them would exceed those of the Cape Observatory. The incomes of the greater portion of the observatories of the world, both public and private, are far less than those mentioned above.

"The work of the Greenwich Observatory may fairly be compared with that of the Naval Observatory, since both institutions are supposed to cover nearly the same field. It might well be asked whether the Naval Observatory, with much greater resources than the Greenwich Observatory, furnishes contributions to astronomy of equal value.

"The conditions for scientific work in Europe are, however, so different from those in America that it is more instructive to compare the details of organization with those of an American observatory. The Harvard Observatory is selected for three reasons: First, both institutions undertake large pieces of routine work which are beyond the reach of the smaller observatories. In this respect they differ from the other American observatories, whose officers are mainly specialists engaged in individual research. Secondly, the resources of the Harvard Observatory approach more nearly than do any other those of the Naval Observatory. Thirdly, all details of the Harvard work are readily available.

"*Grounds.*—The Naval Observatory grounds cover seventy acres, valued, with the improvement made of the grounds, at \$66,000. The Harvard Observatory grounds cover seven acres, having an estimated value of \$50,000. These last grounds are too small and too near thickly settled portions of the city. The climates of Washington and Cambridge are not suitable for astronomical observations of the highest grade. Harvard has established a secondary station in Arequipa, Peru, at a height of 8,000 feet, selected after careful study as the location in which the atmospheric conditions are more favorable than had been found in any other part of the world. Six meteorological stations, extending from the sea-level to a height of 19,200 feet are associated with it. The observatory is also

closely related with the Blue Hill Meteorological Observatory, which is not included in the present discussion.

"Buildings.—The buildings of the Naval Observatory are valued at \$457,512.83; those at Cambridge, at \$52,000; and those at Arequipa, at \$12,000. The Harvard buildings are very inadequate, and for the most part are not fire-proof.

"Instruments.—The principal instruments at the Naval Observatory are the twenty-six-inch equatorial telescope, the twelve-inch equatorial telescope, the nine-inch transit-circle, the six-inch transit-circle, the five-inch altazimuth, and the prime vertical transit instrument. In general, the work done with these instruments does not differ from that done elsewhere. The nine-inch transit-circle is not now in use, but in the past it has done useful work, including the observation of one of the international zones. The principal Harvard instruments at Cambridge are the fifteen-inch equatorial telescope, the fifteen-inch reflector, the twelve-inch meridian-photometer, the eleven-inch Draper telescope, the eight-inch transit-circle, the eight-inch Draper doublet, the six-inch equatorial telescope, and the four-inch transit-photometer. The principal instruments at Arequipa are the twenty-four-inch Bruce doublet, the thirteen-inch Boyden, visual and photographic, equatorial telescope, the eight-inch Bache doublet, the four-inch meridian-photometer, and the four-inch transit-photometer. The eight-inch transit-circle is not now in regular use, but with it two of the international zones have been observed. All of the other instruments are in regular use every clear night, nearly all of them until dawn, and the work done with them is not duplicated elsewhere.

"Permanence of Direction.—Each piece of work undertaken at a large observatory should extend over several years, and in some cases indefinitely. Changes greatly diminish the value, and should be made only when absolutely necessary. Continuity of work is best secured by long tenure of office of the executive officer. At the Naval Observatory ten Superintendents have held office during the last thirty-three years, not including those serving *ad interim*, the average term being three years and one third. Some of these served two or three times, with intervals filled by other officers. (See Appendix, Exhibit I) The rules of the service render difficult the long continuance of an efficient officer on shore duty. The Greenwich Observatory, established in 1675, has had eight directors in two hundred and twenty-four years, the average term being twenty-eight years. The Harvard Observatory, established in 1840, has had four directors in fifty-nine years, the average term being fifteen years. Of these two institutions, nine of the directors have died in office, one retired at the age of eighty years, and none of them have ever resigned to accept positions elsewhere.

"Salaries.—The principal item in the expenses of an active observatory is the salaries of its officers. For the Naval Observatory this item amounts to five sixths of the entire expenditure. It is, therefore, of importance to compare the scale of salaries and the proportion of high and low grade officers. The approximate number of persons of various grades and their average salaries at the Naval and Harvard Observatories are given below:—

	<i>Naval Observatory.</i>		<i>Harvard Observatory.</i>	
Directors	2	\$4,000	1	\$5,000
Astronomers	4	3,000	6	2,000
Assistant Astronomers .	3	1,900	13	900
Computers	8	1,200	18	600
Skilled Artisans	6	1,200	1	700
Laborers	20	700	3	600
	—		—	
	43		42	

It should be stated, however, that some of the assistants at Harvard devote only a portion of their time to this work and receive proportional salaries, the effect not being sufficient to materially alter the conclusions.

"The dual head of the Naval Observatory is, of course, the most striking feature in this comparison. This alone gives an undue cost to the management of the Naval Observatory. The salary of the Astronomical Director is small, considering the importance of the position. As he is a professor of mathematics, his salary may be \$2,400, \$2,800, \$3,200, or \$3,500. The Superintendent, in addition to his salary, has the use of a suitable house. A house is provided for the Director at the Harvard Observatory, but the rent is deducted from his salary. It has not been customary for the Superintendent of the Naval Observatory to take part in the scientific work of the institution and the Astronomical Director does not make observations. The Harvard directors, in addition to their work in the day-time, have always taken part in the observations, the work for the last twenty years averaging over four hours on every clear evening.

"In nearly all military and civil establishments the officers of low grade are much more numerous than those of high grade. There are many more captains than admirals. At the Naval Observatory this difference is much less than at Harvard. At both institutions the observations consist mainly of large pieces of routine work. These are planned by the directors and astronomers, who may also make the observations; but the great labor of computation and reduction is done by the assistant astronomers and computers. The latter can do as much of this work, which is often mere copying, as officers receiving much higher salaries, and it will be noticed that their number at Harvard (thirty-one) is nearly three times that at Washington (eleven). The naval appropriations provide for an instrument-maker, an electrician, a photographer, a carpenter, an engineer, and a skilled laborer. At Harvard there is one instrument-maker, who, however, has a machine-shop. No adequate shop is provided at Washington. The photographic and similar work at Cambridge is done mainly by the assistant astronomers and computers. Ten of the laborers at Washington take care of the grounds, which are ten times as extensive as those at Cambridge. The large number of watchmen (six and a captain of the watch) is perhaps justified by the value of the property to be guarded. The great difference in salaries at Washington and Cambridge, especially for the officers of lower grade, is probably unavoidable. This is partly due to civil-service rules, which, as sometimes administered, also render it difficult to discharge a man who proves to be unfit for his position. The alternative of political appointments would however be fatal to the scientific usefulness of the institution.

"It is evident that the liberal appropriations made to the Naval Observatory should render it the greatest observatory in the world. The principal hindrances, as compared with other observatories, seem to be: (1) The relation of the observatory to the Government, which makes its management complex; (2) frequent changes in its executive officer, which renders a policy of long continuance difficult; (3) the salaries must be much higher than in private institutions to secure equally good men; (4) promotions in cases of special skill, and removal in cases of inefficiency, are difficult; (5) specific expenditures must be provided for in advance, and cannot be changed if conditions alter. Many of these difficulties would be diminished with an efficient and active executive, thoroughly familiar with the scientific work of the institution and having power to enforce needed reforms. A Board of Visitors, independent of Government control, but having power to make necessary changes, would greatly aid such an executive."

The Board of Trustees of the University of Indiana have decided to build an observatory, the principal instrument of which is to be a first-class twelve-inch refractor.

1899, AT 7:30 P. M.

LIST OF MEMBERS ELECTED NOVEMBER 25, 1899.

Mr. FELIPE VALLE } Director National Observatory,
Tacubaya, Mexico.

Mr. FRANCIS SINCLAIR, of Berkeley, was elected to Life Membership.

Adjourned.

The following papers were presented :—

- Adjourned.**

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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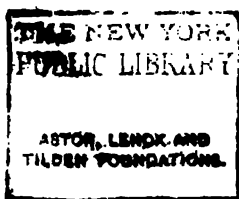


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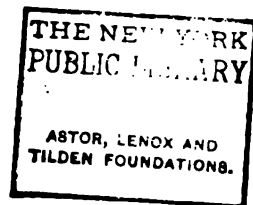
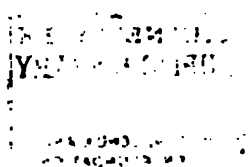
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SIMON NEWCOMB.

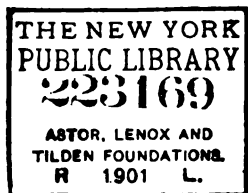
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NOTES ON THE ZODIACAL LIGHT:

BEING A SUMMARY OF OBSERVATIONS MADE AT SEA SINCE 1889.

BY FRANCIS J. BAYLDON, R. N. R.

During the last ten years I have paid great attention to the Zodiacal Light, whilst engaged in a nautical career, in all latitudes from 55° N. to 55° S. Having lately found that its appearance causes great interest amongst many people who have less favorable opportunities for observing it, the following brief summary of my observations may prove of interest, — though scientific accuracy is not pretended, owing to my rough, primitive modes of observations, my attention to the Light being chiefly given to while away otherwise tedious watches on deck. And no undue importance must be attached to these notes; for they are simply the results of one individual's observations, totally uncorroborated by reference to observations by others.

The actual observations given have all been made during the past twelve months, in the Pacific Ocean, whilst on board the Canadian-Australian R. M. S. *Aorangi*, trading between Sydney, N. S. W., and Vancouver, and are chosen out of scores of observations, as being of more especial interest.

As the result of my observations, it seems to me —

I. That when favorably situated, as in tropical regions, an observer may see the eastern and western cones every morning and evening, provided the sky is clear and the Moon is in her first or last quarter.

II. That on every very clear moonless night the Light is visible as a band, reaching across the entire sky throughout the whole night.

III. That frequently when the night is not clear enough for this entire band to be seen, portions of both eastern and western branches may be observed at midnight.

IV. That that part of the band situated in direct opposition to the Sun is generally (especially near the solstices) brighter than the surrounding portions. This brighter portion, elliptical in shape and about 15° long, is known as the *Gegenschein*, and appears to change its position slightly, from 2° or 3° east to 2° or 3° west of the anti-solar spot.

V. That the Zodiacal Light forms an unbroken band uniform

in breadth, around the Earth. This uniform breadth being, approximately, 29° . (See pages 23-24 of this article.)

VI. That this band is inclined about 4° to the plane of the Ecliptic, its line of central axis (approximately) crossing the Ecliptic in R. A. 0^h , reaching its most northerly Declination of $27\frac{1}{2}^{\circ}$ in R. A. 6^h ; again crossing the Ecliptic in R. A. 12^h , reaching its most southerly Declination of $27\frac{1}{2}^{\circ}$ in R. A. 18^h ; again crossing the Ecliptic in R. A. 0^h .

VII. That as an observer moves to the northward, this line of central axis appears displaced to the northward; and as he moves to the southward it appears displaced to the southward, the displacement being 1° for about 19° change in latitude. This displacement seems to be greatest at small elongations from the Sun, as at the base of the cones, and seems to decrease as the elongation increases, towards the apices of the cones, and opposition. Besides this displacement, there is also another, evidently due to the refractive and absorptive properties of the atmosphere, whereby the base and lower portions of the cones are thrown still farther to the northward in north latitudes, and to the southward in south latitudes.

VIII. That there are probably slight seasonal changes in the angle which the band makes with the Ecliptic; but owing to my ever-moving, seafaring life, all such changes I have to associate with my change in latitude, especially as I never record observations ashore, those obtainable in the clearer air at sea appearing to me to be so much more reliable and better.

IX. That the apparent eastern and western cones (or spindles) are chiefly formed by atmospheric effects on the band lying immediately above the horizon, and partly by the increasing extent of circles of altitude from the zenith downwards, but that really the band is uniformly about 22° broad from horizon to zenith. These cones are particularly exaggerated in extra-tropical regions, in the tropics being hardly noticeable.

X. But that the Light is considerably brighter to an elongation of about 105° on either side of the Sun, and under favorable conditions the apices of eastern and western cones always appear to be situated at this elongation, though if the night is unfavorable they are, of course, not seen to this extent.

XI. That beyond these cones the Light can still be traced, very faint, with varying breadth, according to the clearness of the atmosphere, from 5° broad to an average breadth of 12° , to an

extreme breadth of 22° , which is seldom seen, lying beyond the zenith right down to the eastern horizon at P. M., and to the western horizon at A. M. Whereas the cones rapidly taper from an apparent breadth of, say 30° , at the horizon to 10° at their apices, beyond them the band tapers only 2° or 3° in its path across the entire sky; and as the western cone sets and is followed by the band, so the band assumes a cone shape (very faint in intensity); or over the eastern horizon the light appears cone-shaped, but as it rises to the zenith it becomes of a uniform breadth.

XII. That the appearance of the Light is that of a soft white luminosity, and although slight tinges of color are occasionally noticeable, these are entirely due to atmospheric conditions. In brightness the Light, at elongation less than 105° from the Sun, frequently exceeds the brightness of the Galaxy, though at greater elongations it seldom approaches it. Occasionally I have seen the cones so bright that only stars of the second magnitude were discernible in them, but as a rule those of the third magnitude are visible. The connecting band between the cones is very faint indeed, though at times I have traced it across the sky about as bright as the Magellanic clouds. Both in the cones and the connecting band the Light appears brighter and more concentrated towards the line of central axis. So faint is the connecting band that frequently the brighter Gegenschein can be seen, on moderately clear nights, as a separate luminosity, no sign whatever of the band being visible.

XIII. That the Moon adds sufficiently to the Zodiacal Light to make it visible during her first and last quarters; but that from her first to last quarters her light totally absorbs its light, until she is below the horizon.

XIV. That the very faintest cirrus haze is most annoying and aggravating to observers of the Zodiacal Light, as it causes its boundaries to be apparently continually changing, and also its brightness to be constantly waxing and waning, whilst the presence of the haze itself would otherwise be hardly discernible in the sky.

XV. That Honolulu is most favorably situated, as regards latitude and clearness of air, for observations of the Zodiacal Light; that the air over the Pacific Ocean appears clearer and better adapted for observations than that lying over the Atlantic Ocean; and that from high upland plains the Light must present a magnificent spectacle.

A FEW REMARKABLE OBSERVATIONS OF THE ZODIACAL LIGHT
AS SEEN FROM THE PACIFIC OCEAN, FROM NOVEMBER 30,
1898, TO AUGUST 18, 1899.

Nov. 30, Dec. 1 and 2, 1898. — 7 P. M. to about 9:30 P. M.
(Lat. of R. M. S. *Aorangi* being respectively 2° S., 7° S., 12° S.,
and Long. 172° W. to 176° W.)

During these nights the Light was distinctly visible from *Sagittarius*, in the western horizon, to *Pisces*, at the zenith, to *Gemini*, rising in the eastern horizon. Each of the three nights it was thus visible from soon after sunset until a little after moonrise, when gradually its light was absorbed about 9 P. M., 9:30 P. M., 10:15 P. M., respectively. At the western horizon the Light was diffused over some 30° of arc, gradually becoming of less extent, until at the borders of *Pisces*, 60° above the horizon, it had contracted to about 10°. To this point the Light surpassed the brilliancy of the Galaxy in *Aquila* and *Cygnus*, and thence continued as a faint but distinctly visible band, from 15° to 10° broad, across the sky until lost in the Galaxy at the eastern horizon. The line of central axis coincided with that given on pages 23-24 of this paper. Moonshine prevented further observations being made during the night. A brighter ill-defined glow, was apparent between the *Pleiades* and the Galaxy (evidently the *Gegenschein*), and situated on the line of central axis of the band.

January 16th — Midnight.

R. M. S. *Aorangi*. — Lat. 18° N.; Long. 160° W.

Moonset, 10:45 P. M. Light nearly equal to the Galaxy from *Pisces* (western horizon) to near the Galaxy in *Taurus*. Then between 11 P. M. and midnight perfectly discernible, though very dim and diffused, from the Galaxy in the zenith through *Gemini* and *Cancer*, where it brightened a little (the *Gegenschein*), widely diffused through *Leo* into *Virgo* and *Corvus* at the eastern horizon. After 11 P. M. the sky was remarkably clear — had it been only moderately so, the only trace of the eastern Light would have been a bright glow over the eastern horizon, as had been seen the previous night in *Virgo* and *Leo*, 30° high, and also on the succeeding night to the same extent.

February 1st — 8 — 11:30 P.M.

R. M. S. *Aorangi*, at Comox, Vancouver I.—Lat. $49^{\circ} 25' N.$

Very clear, frosty night. Thermometer 20° . Western cone bright as the Galaxy in *Perseus* to the *Pleiades*, about 65° altitude. Twenty degrees broad in *Aries*, lower portion apparently enormously displaced to the northward, but land interfered with observations at a low altitude, as did the Galaxy at very high ones. However, the band was distinctly visible from *Gemini* to near eastern horizon below the Sickle. After 11:30, clouds formed.

July 1st — 7 — 7:30 P.M.

R. M. S. *Aorangi*.—Lat. $1^{\circ} N.$; Long. $169^{\circ} W.$

Light extraordinarily bright over western horizon, to an altitude of about 20° and breadth of 60° , extending from the head of the *Lynx* to *Monoceros*. Intensity nearly equaled that of a second-magnitude star, the only stars in *Leo Major* which could be distinguished in its glow being α , β , γ . The Galaxy could not be compared to it. Above *Leo* it assumed its ordinary breadth and intensity to a little beyond *Spica*, over 90° from the western horizon. After 8 P.M. ordinary conditions prevailed, until cirrus haze spoilt further observations at 11:30 P.M., a faint glow having hung over the eastern horizon in *Aquarius* and *Capricornus* since 10:30. At midnight this eastern glow had increased in intensity, but moonrise, soon after 2 A.M., put an end to observations.

July 3d — 0:30 — 2:30 A.M.

R. M. S. *Aorangi*.—Lat. $9^{\circ} N.$; Long. $167^{\circ} W.$

Sky totally overcast till midnight; then clouds dispersed, leaving the heavens beautifully clear. From 0:30 to 2:30 A.M. the east branch was distinctly visible, being bright and cone-shaped within *Aries* and *Cetus* up to the Southern Fish; then faintly diffused light some 17° broad through *Aquarius* and *Capricornus*; then, very faint, it continued through *Sagittarius* into the Galaxy, broadening out into the Gegenschein at the border of the Galaxy around σ , τ , χ , ϕ , ν *Sagittarii*. The western branch was too low to be suitable for observation. At 2:30 A.M. clouds again formed. The following evening, from 9 P.M. to midnight, through breaks in the clouds, the Light could be seen in *Leo*, *Virgo*, and *Libra*; the Gegenschein was also visible; and a slight glow over the eastern horizon in *Capricornus*, *Aquarius*, and *Pisces*.

The evening of July 4th (Lat. 15° N.; Long. 162° W.), also corroborated the visibility of the Light in the above-mentioned constellations,—and probably in *Scorpio* also,—over both eastern and western horizons, from 9 P.M. to midnight, when clouds formed. The Gegenschein was also visible.

On the evening of July 5th, 7:45 to 8:15 P.M., the Light was intensely bright, practically equal in intensity to a second-magnitude star, to an altitude of 20° above western horizon (in *Leo*), with a maximum breadth of only 15° , there being no diffused light visible. At 9:30 P.M., the Gegenschein was inclosed by the stars 1° south of σ , τ , χ , ψ , π , ϕ , ζ , ν *Sagittarii*. Clouds interfered later.

July 6th — 8 – 9 P.M.

R. M. S. *Aorangi*, off Isle of Oahu, H. I.

Light equal to star of magnitude 2.5, again in *Leo*; then gradually declined. Much broader than last night, with a big northerly displacement (nearly to μ *Ursæ Majoris*). Gegenschein as last night, perhaps a little more easterly. At midnight eastern horizon had a good glow over it.

July 7th.—Very good bright observations again obtained till midnight of both western and eastern branches and of the Gegenschein.

July 8th. (Lat. 30° N).—Throughout the entire night no clouds came to spoil observations, so that the Light could be seen uninterruptedly from horizon to horizon, and also the Gegenschein, during all the night. From 3 to 4 A.M., the east branch was magnificently bright. During this night the Light was visible in every zodiacal constellation excepting *Cancer* and *Gemini*, the two nearest the Sun.

Another fine “run of luck” was experienced when bound south, from August 5th (Lat. 15° N.) to August 18th (Lat 30° S.). The outlines, as well as my “home-made” charts would allow, are given, and show apparent change in the line of central axis as we proceeded south.

August 5th, 8 P. M., to August 6th, 3 A. M.

R. M. S. *Aorangi*.—Lat. 15° – 14° N., Long. $161\frac{1}{2}^{\circ}$ W.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
2° N. β <i>Leonis</i> .	1° N. β <i>Virginis</i> .	About 2° N. θ <i>Crateris</i> .
3° N. δ <i>Virginis</i> .	η " "	2° N. δ <i>Corvi</i> .
1° N. ζ " "	2° N. α " "	3° N. γ <i>Hydræ</i> .
5° S. μ " "	$1\frac{1}{2}^{\circ}$ S. α <i>Libræ</i> .	5° N. π " "
4° S. β <i>Libræ</i> .		2° N. 20 <i>Libræ</i> .
[Galaxy intervenes.]		
0 <i>Sagittarii</i> .	$2\frac{1}{2}^{\circ}$ S. π <i>Sagittarii</i> .	1° N. σ <i>Sagittarii</i> .
1° S. β <i>Capricorni</i> .	θ <i>Capricorni</i> .	ψ " "
ξ <i>Aquarii</i> .	Just N. σ <i>Aquarii</i> .	1° S. χ <i>Capricorni</i> .
Just S. γ and η " "	ϵ <i>Piscium</i> .	δ <i>Aquarii</i> .
β <i>Piscium</i> .	τ <i>Arietis</i> .	4° N. ι <i>Ceti</i> .
$4\frac{1}{2}^{\circ}$ S. γ <i>Pegasi</i> .	1° S. <i>Pleiades</i> .	Just S. 20 " "
β <i>Arietis</i> .		2° S. ν <i>Piscium</i> .
ζ <i>Persei</i> .		δ <i>Tauri</i> .

8–9 P.M.—A faint diffused light visible over the western horizon. Line of central axis not as far north as when I last saw it, in Lat. 42° N.

10 P.M.—Night clearer. Gegenschein distinctly visible in the center of the body of the Goat.

11 P.M.—The Gegenschein has faint bands extending 4° broad east and west. Westward in *Capricornus* and *Sagittarius*; eastward through *Aquarius* and *Pisces* to *Aries* at the horizon, being cone-shaped between *Pegasus*, *Pisces*, and *Cetus*.

0–0:30 A.M.—Eastern branch faintly visible from horizon, *Taurus* to Galaxy.

3 A.M.—Eastern branch distinctly visible to Galaxy. Gegenschein distinct.

The above outlines were obtained in the course of the night.

August 6th— Lat. 11° N.

8–10 P.M.—Night cloudy. Observations of the western branch and Gegenschein only obtained.

Publications of the

August 7th — Lat. 6° N; Long. 167° W.

8 – 10 P.M. — Cloudy. Western branch moderately distinct — widely diffused through *Virgo*, *Libra* to Galaxy. Gegenschein visible.

11 – Midnight. — Sky clear. Gegenschein distinct, but boundaries vague — oval-shaped roughly, lying between 2° or 3° north of τ and 29 ; θ , ϵ , κ , δ *Capricorni*, 2° south of λ *Aquarii*. Eastern branch visible from *Aries* to Galaxy.

1:30 A.M. — Very good observations. Light quite plain, from a little north of *Pleiades* to Galaxy.

Outlines obtained this night are contained in the next list.

August 8th — Lat. 1° N.; Long. 170° W.

8:30 P.M. — Light moderately bright, nearly equal to Galaxy; visible from *Virgo* (western horizon) round to *Aquarius* over eastern horizon, including the Gegenschein.

9 P.M. — Could distinguish connecting bands from Gegenschein to Galaxy, and Gegenschein to 10° above eastern horizon.

10 P.M. — This eastern branch more distinct from *Cetus* to Galaxy.

10 – Midnight. — Cone-shaped glow from *Aries* (eastern horizon) to Galaxy, quite distinct. Gegenschein region during the nights of the 5th, 6th, 7th, and 8th, was very puzzling and irregular. It appeared as an oval-shaped luminosity contained between curves drawn from 2° south of λ *Aquarii*, 1° north of θ *Capricorni*, η , χ , ζ 36 , v , μ *Capricorni*. South of the curve, μ , v , 36 *Capricorni*, there seemed to be no light at all, and then another bright narrow curve surrounding 36 ϵ , κ , δ , v , μ *Capricorni*. The whole region being in the Zodiacal band.

1 A.M. – 3:30 A.M. — Beautifully clear night. Eastern branch very distinct from horizon (*Aries*) to the Galaxy (*Sagittarius*). Outlines given in next list. Cloudy at 4 A.M.

August 9th — Lat. $4\frac{1}{2}^{\circ}$ S.; Long. 172° W.

8:30 – Midnight. — Cirrus haze and cumulus prevalent. At intervals west branch fairly bright. East branch well visible as before; also, the Gegenschein, the dark southern portion not being so plainly marked. Observations most satisfactorily corroborated previous nights. These outlines are now given:—

Outlines of the Light seen on August 7th, 8th, 9th.

R. M. S. *Aorangi* — Lat. 6° N. to $4\frac{1}{2}^{\circ}$ S., Long. 167° to 172° W.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
ϵ <i>Virginis</i> .	$3\frac{1}{2}^{\circ}$ S. γ <i>Virginis</i> .	γ <i>Corvi</i> .
τ "	$1\frac{1}{2}^{\circ}$ N. α "	2° N. γ <i>Hydræ</i> .
μ "	1° S. α <i>Libræ</i> .	$1\frac{1}{4}^{\circ}$ N. π "
2° N. β <i>Libræ</i> .	δ <i>Scorpii</i> .	Just N. ϕ <i>Libræ</i> .
48 "		
1° N. χ "		
[Galaxy intervenes.]		
Bet'n ξ and σ <i>Sagittarii</i> .	σ <i>Sagittarii</i> .	ζ <i>Sagittarii</i> .
1° S. β <i>Capricorni</i> .	ψ "	ϵ "
Just S. ξ <i>Aquarii</i> .	1° S. θ <i>Capricorni</i> .	1° S. ξ <i>Aquarii</i> .
" S. γ and η <i>Aquarii</i> .	μ "	2° S. δ "
β <i>Piscium</i> .	λ <i>Aquarii</i> .	ι <i>Ceti</i> .
3° S. γ <i>Pegasi</i> .	ζ <i>Piscium</i> .	Just N. α <i>Piscium</i> .
α <i>Arietis</i> .	Just N. of <i>Ecliptic</i> .	" N. ν <i>Ceti</i> .

August 10th.

R. M. S. *Aorangi*. — Lat. $9\frac{1}{2}^{\circ}$ S.; Long. 175° W.

9 P.M. — After moonset west branch fairly bright — brighter than of late — to the Galaxy. Outlines much as before, but not quite so far north. Gegenschein visible from 8 P.M., nearly circular, with blank space as before; but the whole Gegenschein is brighter than of late, and the blank space showed the slightest luminosity, though still darker than the surrounding portions, towards 11 P.M., when it was overhead.

10 P.M. — Night magnificently clear. East branch quite distinct and very broad, rather more to the south than of late. The full outlines easily seen were 19° broad, across the sky, the broadest I have yet seen the connecting band. Its center was brighter and more concentrated for a breadth of 10° , and the Gegenschein formed part of this brighter central portion.

Midnight. — The Light formed a uniform broad path of luminosity across the sky, fully equal to the less illuminated parts of the Galaxy.

1 A.M. — Still continued to a uniform breadth of 19° or 20° from the *Pleiades* to the Galaxy in *Sagittarius*, and appeared so strikingly that I woke up our fourth officer to witness the spectacle. The Gegenschein appeared as a brighter patch in the

midst of the band, with a darker central portion, which was the darkest portion of the sky in the track of the Light—from *Taurus* to *Sagittarius*—i. e. from the eastern horizon to some 40° above the western.

4–5 A.M.—Light very distinct, forming a cone fully equal to a third-magnitude star, from eastern horizon between *Procyon* and about 51 *Aurigæ*, then maintained a contracted uniform breadth of 15° to 12° to the Galaxy in western horizon. The bright cone was of uniform brilliancy throughout, and crossed the Galaxy, which was not visible at all.

Outlines given in next list.

August 11th—Lat. 14° S.; Long. 178° W.

11:45 P.M.—Overcast until now. Clouds moving away from the eastward, leaving that direction intensely clear.

0–0:15.—Eastern branch *ridiculously* bright, equal to the normal condition of the Galaxy, for which it has just been mistaken by a friend!—from horizon to the Gegenschein, the light being uniformly distributed in breadth and intensity, as last night.

Last night's outlines will do. Gegenschein showed the darker patch again with slightest luminosity.

Outlines are now given:—

As seen on August 10th and 11th.

R. M. S. *Aorangi*—Lat. 9° to 14° S.; Long. 175° to 178° W.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
1° N. δ <i>Virginis</i> .	4½° S. γ <i>Virginis</i> .	δ <i>Corvi</i> .
ζ "	1° S. α "	1° N. γ <i>Hydræ</i> .
1° S. δ <i>Libræ</i> .	4½° S. α <i>Libræ</i> .	π "
Bet'n η and γ <i>Libræ</i> .	1° S. α <i>Scorpii</i> .	3° S. ϕ <i>Scorpii</i> .
2° N. ν <i>Scorpii</i> .		
[Galaxy intervenes.]		
2° N. ξ <i>Sagittarii</i> .	τ <i>Sagittarii</i> .	γ <i>Corollæ</i> .
β <i>Capricorni</i> .	½° N. χ <i>Capricorni</i> .	2° N. α <i>Microscopii</i> .
ξ <i>Aquarii</i> .	2° S. ι <i>Aquarii</i> .	2° N. η <i>Piscis Aust.</i>
η "	2° S. λ "	2° N. 88 <i>Aquarii</i> .
β <i>Piscium</i> .	1° S. Dec.; R. A. 0 ^b	2° S. ι <i>Ceti</i> .
1° S. γ <i>Pegasi</i> .	ζ <i>Piscium</i> .	5° N. θ "
1° N. α <i>Arietis</i> .	1° S. δ <i>Tauri</i> .	2° N. γ "
ζ <i>Persei</i> .	3° S. β "	o <i>Tauri</i> .
2° N. θ <i>Aurigæ</i> .	1° N. ϵ <i>Geminorum</i> .	4° S. α "
About 51 "	3° N. δ "	2° S. ν <i>Orionis</i> .
		<i>Procyon</i> .

My next observations were obtained (owing to cloudy weather) from midnight to 1:30 A.M., on August 15th, in latitude 19° S. Light was discernible from *Aries* to the Galaxy; not as clear as on the 11th and 12th, but still forming a broad band. Gegenschein but little brighter than the band, with a darker interior as before. On August 16th, Lat. 22° S., Moon set at 1 A.M., and Light was again very distinct, with same outlines as last given from Gegenschein to *Aquarius*, then southern border remained the same to 2° north of α *Ceti*, whilst northern border was fore-shortened, passing 2° south of η *Aquarii*, thus placing line of central axis slightly to the southward of that given in the above list. Gegenschein region very indistinct and puzzling,—the band is very faint there,—and I do not believe the Gegenschein itself is visible.

On the mornings of the 17th and 18th, between 4 and 5 A.M., the Light was fairly bright—traceable to about 40° from the western horizon. No Gegenschein was discernible.

A long stay ashore in Sydney then interfered with my observations.

Below are given the outlines of the Zodiacal band as obtained from observations taken in both north and south latitudes. They give an extreme breadth to the band of 29° – 30° . To an observer in a fixed locality the average breadth appears about 22° only, at the favorable elongation of 40° from the Sun; but if he were to move to the northward or southward he would find the northern or southern boundary extending, and thus this extreme limit of 29° – 30° has been obtained.

EXTREME OUTLINES OF THE ZODIACAL BAND (AND NORMAL LINE OF CENTRAL AXIS) FORMING A BAND ABOUT 29° BROAD ACROSS THE ENTIRE SKY.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
2° N. γ <i>Pegasi</i> .	Just S. δ <i>Piscium</i> .	$2\frac{3}{4}^{\circ}$ S. ι <i>Ceti</i> .
<i>a</i> <i>Triang</i> .	Just N. ϵ <i>Arietis</i> .	1° S. α <i>Piscium</i> .
4° S. β <i>Persei</i> .	<i>Pleiades</i> , just N. η <i>Tauri</i> .	<i>o</i> <i>Tauri</i> .
$1\frac{1}{2}^{\circ}$ N. η <i>Aurigæ</i> .	Just S. β <i>Tauri</i> .	4° S. α " "
2° S. β " "	$1\frac{1}{2}^{\circ}$ S. β <i>Geminorum</i> .	1° S. ν " "
$10\frac{3}{4}^{\circ}$ N. α <i>Gemin</i> .	$1\frac{1}{2}^{\circ}$ N. γ <i>Cancr</i> i.	1° N. ζ <i>Geminorum</i> .

1° N. α <i>Lyncis</i> .	1½° S. η <i>Leo. majoris</i> .	1½° N. β <i>Cancr.</i>
1½° N. δ <i>Leo. min.</i>	σ "	1½° N. ζ <i>Hydræ</i> .
2½° N. ξ <i>Virginis</i> .	β "	4½° N. μ <i>Sextan.</i>
μ "	1° S. α "	1° N. γ <i>Corvi</i> .
2½° S. ζ <i>Ophiuchi</i> .	3½° N. 20 <i>Libræ</i> .	2½° N. γ <i>Hydræ</i> .
4½° S. ν "	Just N. π <i>Scorpii</i> .	4½° S. π "
3½° N. ϵ <i>Sagittarii</i> .	1° S. α "	6½° N. κ <i>Centauri</i> .
1° N. ϵ <i>Aquarii</i> .	1½° N. δ <i>Sagittarii</i> .	Just N. θ <i>Scorpii</i> .
1° N. μ "	τ "	2° N. ι <i>Sagittarii</i> .
1° N. β "	Just N. χ <i>Capricorni</i> .	1½° S. η <i>Piscis Aust.</i>
1° S. α "	2° S. ι <i>Aquarii</i> .	ϵ " "
4½° N. γ <i>Piscium</i> .	2½° S. λ "	Just S. 98 <i>Aquarii</i> .
	R. A. 0 ^h ; Dec. 0°.	104 "

The above are the outlines as they appear to me, deduced from observations in all latitudes from 55° N. to 55° S.

It also seems to me that to a northern observer the northern boundary will appear about the same, and the southern boundary less southerly than here given, with a consequent displacement to the northward of the line of central axis of about 1° for every 19° of latitude he is distant from that part of the sky he is observing (*vice versa* in southern latitudes). At times, also, the band appears broader than here given, as if the Light extended still farther; but so faint, attenuated, and vague are such boundaries, that I have ignored them.

Extreme accuracy must not be expected, for only star-charts of a primitive nature have been employed for laying off my observations.

R. M. S. "WARRIMOO," VANCOUVER, B. C., Dec. 4, 1899.

OBSERVATIONS OF VARIABLE STARS.

BY ROSE O'HALLORAN.

(Continuation of observations in No. 71 of these *Publications*.)

- Oct. 22. α *Ceti* is slightly less than ξ *Piscium* in brightness.
 28. Ditto.
 31. Scarcely brighter than 69 *Ceti* on a clear dark sky.
 Nov. 21. Equal to 71 *Ceti*.

- 29. It seems less than 7 r .
 - 30. It seems equal to 7 r .
 - Dec. 1. Less than 7 r .
 - 2. Ditto.
 - 5. Ditto.
 - 8. Equal to the star of 8.2, magnitude south of 7 r .
 - 17. It is less than 8.2, but brighter in moonlight than adjacent star of 8.4 magnitude.
-

- Oct. 22. *W Lyrae* is brighter than an adjacent star classed as of 12th magnitude, and equal to one classed as 10th.
- 23. Ditto.
- 28. Brighter than 10th magnitude, but not as bright as one to the north classed as 8.6; it is probably of about 9th magnitude.
- 31. It has undergone a rapid decrease, and is again of 10th magnitude.
- Nov. 1. Ditto.
- 4. It is now of 9th magnitude.
- 6. Ditto.
- 21. It is brighter than 9th magnitude, but not equal to star of 8.6 magnitude.
- 22. There is a slight decrease.
- 29. Probably of 9th magnitude.
- 30. Ditto.
- Dec. 1. Ditto.
- 2. Ditto.
- 3. Ditto.
- 5. Ditto.
- 6. Ditto.
- 17. It equals a comparison star of 8.6 magnitude.

SAN FRANCISCO, 1899.

PLANETARY PHENOMENA FOR MARCH AND
APRIL, 1900.

BY MALCOLM MCNEILL.

MARCH.

The Sun passes the vernal equinox and Spring begins March 20th, 5 P. M., P. S. T.

At the beginning of the month *Mercury* is an evening star, setting an hour and twenty minutes after the Sun. This interval increases slightly until March 8th, when the planet reaches greatest east elongation. After that the distance between Sun and planet rapidly diminishes, and inferior conjunction is reached on March 24th, when the planet changes to a morning star. The March elongation and the one which will come early in July afford the best opportunities of the year for seeing *Mercury* in the evening.

Venus is an evening star well out toward greatest east elongation. It is still increasing its distance from the Sun, and is moving rapidly eastward and northward among the stars. At the end of the month it sets nearly four hours after sunset. It moves from the constellation *Aries* into *Taurus*, and at the end of the month it is near the *Pleiades*, a little south and west.

Mars still keeps its position as a morning star, rising about half an hour before sunrise. Its apparent distance from the Sun increases a little during the month.

Jupiter rises earlier, at 1:14 A. M. on March 1st, and at 11:20 P. M. on March 31st. It is still in the constellation *Scorpio*, and moves slowly eastward about 1° among the stars until March 27th, when it becomes stationary, and then moves slowly westward.

Saturn by the close of the month rises about 1 A. M. It is in the constellation *Sagittarius*, and moves slowly eastward with diminishing rapidity, as it has nearly reached its stationary point. It will be occulted by the Moon on the morning of March 24th, the occultation lasting from 1:31 to 2:38 A. M. at Washington local time. Times for other parts of the country must be determined separately.

Uranus is near *Jupiter*, in the constellation *Scorpio*. It moves eastward a little until March 17th, and then begins to move

westward. At the end of the month it is 2° east and 1° south of *Jupiter*.

Neptune is still on the border of *Taurus* and *Gemini*, nearly stationary.

APRIL.

Mercury is a morning star throughout the month, and comes to greatest west elongation on April 21st. At this date its apparent distance from the Sun is 9° greater than at the greatest east elongation in March; but the planet in April is so far south of the Sun in declination that it will not be easy to see, the interval between the rising of the planet and sunrise being less than an hour.

Venus is an evening star, and reaches greatest eastern elongation on April 28th, when its apparent distance from the Sun is $45^{\circ} 35'$. Throughout the month it sets about four hours after sunset. It moves from a position near the *Pleiades* in *Taurus* into *Gemini*, 34° eastward and 6° northward, during the month.

Mars is still close to the Sun, and by the close of the month rises about an hour before sunrise, too short an interval to allow the planet to be seen unless under exceptional conditions of weather.

Jupiter rises two hours earlier than during March, and is getting into position for late evening observation. It is retrograding, moving westward in the constellation *Scorpio*, the motion being about 2° during the month, and is almost exactly following the path marked out by its motion in the early part of the year.

Saturn is almost stationary among the stars, moving a little eastward to April 14th, and then moving westward. It rises about two hours earlier than during March.

Uranus is still in the neighborhood of *Jupiter*, and, like it, is retrograding; but the greater westward motion of *Jupiter* causes their apparent distance to increase from 2° , on April 1st, to 3° , on April 30th.

Neptune moves about 1° eastward on the border of *Taurus* and *Gemini*.

EXPLANATION OF THE TABLES.—The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multi-

plied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time, if the place is west of the standard meridian, and *subtracting*, if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

MARCH-APRIL, 1900.

PHASES OF THE MOON, P. S. T.

			H.	M.	
First Quarter, March	7,	9 34 P.M.			
Full Moon, March	16,	12 12 A.M.			
Last Quarter, March	23,	9 36 P.M.			
New Moon, March	30,	12 30 P.M.			
First Quarter, April	6,	12 55 P.M.			
Full Moon, April	14,	5 2 P.M.			
Last Quarter, April	22,	6 33 A.M.			
New Moon, April	28,	9 23 P.M.			

THE SUN.

1900	R. A.		Declination.		Rises.		Transits.		Sets.	
	H.	M.	°	'	H.	M.	H.	M.	H.	M.
Mar. 1,	22	48	—	7 38	6 38	A.M.	12 13	P.M.	5 48	P.M.
11,	23	25	—	3 46	6 22		12 10		5 58	
21,	0	2	+	0 10	6 7		12 7		6 7	
Apr. 1,	0	42	+	4 29	5 49		12 4		6 19	
11,	1	18	+	8 15	5 33		12 1		6 29	
21,	1	55	+	11 48	5 19		11 59	A.M.	6 39	
May 1,	2	33	+	15 1	5 5		11 57		6 49	

MERCURY

Mar. 1,	23	46	—	1 9	7 15	A.M.	1 11	P.M.	7 7	P.M.
11,	0	25	+	5 32	6 51		1 10		7 29	
21,	0	20	+	5 58	6 6		12 26		6 46	
Apr. 1,	23	51	+	0 43	5 12		11 14	A.M.	5 16	
11,	23	51	—	2 2	4 41		10 34		4 27	
21,	0	18	—	0 48	4 23		10 21		4 19	
May 1,	1	1	+	3 25	4 14		10 25		4 36	

VENUS.

Mar. 1,	1 10	+	7 34	8 9 A.M.	2 35 P.M.	9 1 P.M.
11,	1 54	+	12 28	7 56	2 39	9 22
21,	2 38	+	16 54	7 45	2 44	9 43
Apr. 1,	3 28	+	21 1	7 35	2 50	10 5
11,	4 13	+	23 54	7 28	2 56	10 24
21,	4 59	+	25 52	7 26	3 2	10 38
May 1,	5 43	+	26 51	7 26	3 7	10 48

MARS.

Mar. 1,	22 12	—	12 20	6 18 A.M.	11 36 A.M.	4 54 P.M.
11,	22 42	—	9 27	5 59	11 27	4 55
21,	23 11	—	6 25	5 39	11 17	4 55
Apr. 1,	23 43	—	2 59	5 15	11 5	4 55
11,	0 11	+	0 9	4 55	10 54	4 53
21,	0 39	+	3 15	4 32	10 43	4 54
May 1,	1 8	+	6 17	4 11	10 32	4 53

JUPITER.

Mar. 1,	16 33	—	21 5	1 14 A.M.	5 59 A.M.	10 44 A.M.
Apr. 1,	16 38	—	21 11	11 17 P.M.	4 1	8 45
May 1,	16 30	—	20 55	9 11	1 56	6 41

SATURN.

Mar. 1,	18 15	—	22 24	3 1 A.M.	7 40 A.M.	12 19 P.M.
Apr. 1,	18 21	—	22 21	1 6	5 45	10 24 A.M.
May 1,	18 21	—	22 20	11 7 P.M.	3 46	8 25

URANUS.

Mar. 1,	16 44	—	22 14	1 29 A.M.	6 9 A.M.	10 49 A.M.
Apr. 1,	16 45	—	22 14	11 27 P.M.	4 7	8 47
May 1,	16 41	—	22 9	9 26	2 6	6 46 A.M.

NEPTUNE.

Mar. 1,	5 35	+	22 4	11 40 A.M.	6 59 P.M.	2 18 A.M.
Apr. 1,	5 36	+	22 6	9 42	5 1	12 20
May 1,	5 39	+	22 9	7 46 A.M.	3 6	10 26 P. M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

		H.	M.			H.	M.
II, R,	Mar. 2,	11	42 P.M.	II, D,	Apr. 3,	8	52 P.M.
III, D,	6,	11	34	I, D,	6,	4	10 A.M.
III, R,	7,	1	8 A.M.	I, D,	7,	10	38 P.M.
I, D,	7,	2	8	II, D,	10,	11	26
II, D,	9,	11	55 P.M.	III, D,	11,	7	22
II, R,	10,	2	15 A.M.	III, R,	11,	9	1
III, D,	14,	3	31	I, D,	15,	12	31 A.M.
III, R,	14,	5	6	II, D,	18,	2	1
I, D,	15,	10	29 P.M.	III, D,	18,	11	19 P.M.
II, D,	17,	2	28 A.M.	III, R,	19,	12	58 A.M.
II, R,	17,	4	49	I, D,	22,	2	25
I, D,	21,	5	54	I, D,	23,	8	53 P.M.
I, D,	23,	12	23	I, D,	25,	4	35 A.M.
II, D,	24,	5	2	III, D,	26,	3	16
I, D,	30,	2	16	III, R,	26,	4	57
				I, D,	29,	4	19
				I, D,	30,	10	47 P.M.

(THIRTY-SEVENTH) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. E. GIACOBINI, of the Nice Observatory, for his discovery of an unexpected comet on September 29, 1899.

The Committee on the Comet-Medal,

JAMES E. KEELER,
WM. M. PIERSON,
CHAS. BURCKHALTER.

1899, December 2.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DOUBLE-STAR NOTES.

The weather in the year 1899, taken as a whole, was not as favorable for double-star observations as during the year or two preceding. In the first three months, and again in the last three months, of the year, long spells of stormy or cloudy weather interfered seriously with the continuity of observations; and the month of August, usually a good observing month, had but very few nights when the seeing was good enough for the measurement of close pairs. Two hundred and fifty-five double stars were, however, measured during the year, 154 of them being under 1" in distance, and many of them near the limit of the separating power of even the large refractor.

This list includes nearly all the more rapid binary systems, many of the more difficult β stars, and forty-seven new pairs, all under 5", which were found with the twelve-inch telescope. The detailed measures will be published in the *Astronomische Nachrichten*; but notes on some of the more important stars will be of interest.

Procyon: Measures of SCHAEBERLE's companion on three nights give the following position:—

1899.99 $334^{\circ}.5$ $4''.88$

SCHAEBERLE's discovery position was —

1896.874 $318^{\circ}.8$ $4''.59$

The companion is very faint — not brighter than $13\frac{1}{2}$ magnitude — and can only be seen well enough for good measures on the best nights. It is now much harder to measure than the companion to *Sirius*.

Sirius: The companion is increasing its distance from the bright star, and continues its motion in angle. The means of

* Lick Astronomical Department of the University of California.

five measures in angle and four in distance, including measures on one night in this year, are:—

$$1899.896 \quad 145^{\circ}.6 \quad 4''.53$$

ZWIERS'S ephemeris gives for the same date, $147^{\circ}.2 \quad 4''.55$.

β 883: This close and interesting pair was measured on ten nights during the year. The mean of the measures on the last two nights is —

$$1899.906 \quad 56^{\circ}.5 \quad 0''.24$$

Since I began observing this pair in the autumn of 1896, I have measured it on thirty-two different nights — the longest intervals between two successive measures in the past two years being 0.4 years in the spring of 1898, and 0.3 years in the spring of 1899. As the angular change in three years, from 1896.88 to 1899.91, has been only 40° , I think it is now safe to say that this system cannot have a period at all approximating five and a half years. In fact, it seems very possible that the period may finally be found to be more nearly twenty years, as the consecutive character of the measures makes it practically certain that no change of quadrant has taken place in the last two years.

ϕ *Andromedæ*: Measures of this pair on three excellent nights in July give:—

$$1899.557 \quad 231^{\circ}.0 \quad 0''.23$$

The smaller star has been assumed to be in the first quadrant for the last few years; and the angular change since discovery in 1851 as more than 250° . But on these three nights the quadrant was noted with particular care, and as the difference of brightness of the components is nearly one magnitude, and the atmospheric conditions were most favorable, the position here given is undoubtedly correct. The period of revolution of this pair, too, is therefore much greater than has been supposed.

β 1007: This is one of the pairs found by BURNHAM with the twelve-inch refractor during his stay on Mt. Hamilton, in November, 1881. The mean of two nights' measures then gave:—

$$1881.86 \quad 266^{\circ}.2 \quad 0''.27$$

Subsequently, BURNHAM was unable to see the star double with the $18\frac{1}{2}$ -inch Dearborn refractor; and in the years 1890–92 he noted it as single with the thirty-six-inch refractor. During the past year the companion has again appeared in the same quadrant

as in 1881. A measure in 1899.177 gave $244^{\circ}.3 \ 0''.18$, and two later measures give as mean:—

$$1899.724 \ 243^{\circ}.2 \ 0''.22$$

The star is apparently in rapid motion, probably in an orbit whose plane is nearly parallel to the line of sight.

$\beta \ 524 = 20 \text{ Persei}$. This is one of the closest pairs measured during the year. The four measures secured are:—

$$1898.925 \ 47^{\circ}.6 \ 0''.12$$

$$1899.180 \ 31^{\circ}.4 \ 0''.12$$

$$.555 \ 49^{\circ}.2 \ 0''.13$$

$$.557 \ 50^{\circ}.2 \ 0''.14$$

The angle given by the second measure is not in good accord with the other values, and may contain an error of circle reading. The pair, however, is so close and difficult under the best conditions that I have not felt at liberty to reject the discordant measure. BURNHAM's discovery position was —

$$1878.66 \ 338^{\circ}.7 \ 0''.34$$

and his last measure with the thirty-six-inch refractor,—

$$1891.79 \ 281^{\circ}.7 \ 0''.15$$

If the above positions are correct as to quadrant, the pair has, therefore, nearly completed a revolution since discovery.

Some of the other close pairs measured during the year are:—

$$\beta \ 1146, 1899.56 \ 313^{\circ}.6 \ 0''.18$$

$$\kappa \text{ Pegasi}, 1899.4 \ 284^{\circ}.0 \ 0''.19$$

$$\text{Secchi} = BC \text{ of } \Sigma \ 2481, 1899.69 \ 187^{\circ}.9 \ 0''.16$$

$$\beta \ 1185, 1899.92 \ 347^{\circ}.0 \ 0''.14$$

$$\Sigma \ 1865, 1899.53 \ 161^{\circ}.6 \ 0''.16$$

$$\Sigma \ 1989 = \pi^2 \text{ Ursæ Min.}, 1899.53 \ 347^{\circ}.6 \ 0''.16$$

Eighteen other pairs, with distances of less than one quarter of a second of arc, were measured during the year, the closest pair of all being perhaps $\beta \ 953$, of which measures were possible on only one night. These give —

$$1899.714 \ 223^{\circ}.2 \ 0''.10$$

In 1898 the star was found to be single.

R. G. AITKEN.

January, 1900.

COMETS OF 1899.

Five comets in all were discovered during 1899. Of these two only were new, the remaining three being apparitions of short-period comets.

Comet *a* (1899 I) was discovered on March 3, 1899, by Dr. SWIFT, at the Lowe Observatory, Echo Mountain, California. At the time of discovery the comet was moving north and towards the Sun, which it passed on April 12th. During some weeks it was lost while near the Sun, but was picked up again early in May. It attained a north Declination of 57° on May 29th. After perihelion passage, which occurred on April 13th, the comet became much brighter, being estimated at 3.0 magnitude on May 7th (HOLETSCHER).

On May 11th, a second nucleus was observed, which was visible for two weeks.*

The last observation at Mt. Hamilton was on July 31st.

Comet *b* (1899 III), TUTTLE's periodic comet, was rediscovered by Dr. MAX WOLF, at Heidelberg, by means of photography, on March 5th. It was then of 12th magnitude. Its brightness increased as it approached perihelion, which was passed on May 4th. It was last observed in the northern hemisphere on May 1st, when it became lost in the rays of the Sun. After perihelion passage it was observed in the southern hemisphere. This comet has a period of 13.8 years, and was observed at its last return in 1885.

Comet *c* (1899 IV), TEMPEL's second periodic comet, was rediscovered by the writer on May 6th. It was then of about the 16th magnitude, but increased rapidly in brightness as it neared both Sun and Earth. It passed perihelion on July 28th, at which time it was almost in opposition, and only thirty-five million miles distant from the Earth. At this time its brightness was of about the 8th magnitude. This opposition was one of the most favorable possible of this comet. It was last observed at the Lick Observatory on December 1st, when it was of only the 15th magnitude. This comet was observed on its last return to perihelion in 1894.

Comet *d* (1899 II), HOLMES's periodic comet, was rediscovered by the writer on June 10th. It was then very faint—being estimated at 16th magnitude. This comet attracted much

* *Publications A. S. P.*, No. 69, p. 150.

attention at the time of its discovery in 1892, when it was visible to the unaided eye. Its situation was practically as favorable for observation at this appearance as in 1892-93, and yet it has not been brighter than the 14th magnitude.

Perihelion was passed on April 28th. The last observation at Mt. Hamilton was on December 24th.

Comet *c* (1899 V) was discovered by M. GIACOBINI, at Nice, on September 29th. It was then of about the 11th magnitude. Perihelion was passed on September 15th, at a distance of one hundred and sixty-five million miles. Its brightness has decreased slowly. At the last observation, of December 23d, it was estimated to be of the 13th magnitude. It is now too near the Sun to be observed, but will in all probability be bright enough to be observed with large instruments in February or March.

C. D. PERRINE.

1900, January 20.

NOTE ON THE SPECTRUM OF COMET *a* 1899 (SWIFT).

The spectra of the brightest comets of 1898 and 1899 were carefully observed at the Lick Observatory by Mr. WRIGHT. His paper describing the results is published in the *Astrophysical Journal* for October, 1899. One fact established by the observations of SWIFT's Comet (1899 *a*) seems to me to be of great interest and importance.

Mr. WRIGHT's photograph of the spectrum records some fifteen bright lines, of which the lines at wave-lengths 4052, 3880, and 3870 are the strongest. "In the spectrum of the nucleus λ 4052 is fully as bright as λ 3870, but the latter line extends out into the comet's head more than four times as far as the former. In fact, the lines $\lambda\lambda$ 3870 and 3880 experience only a gradual increase in brightness in the region of the nucleus, and extend the entire length of the slit. In the cases of all the other lines, the change is quite abrupt. This must be taken to indicate a marked difference between the spectrum of the nucleus and the spectra of the outer parts of the head."

The lines at $\lambda\lambda$ 3870 and 3880 are due to cyanogen.

It seems not too much to hope that this beginning in detecting differences in the spectra of different parts of comets may, in the case of very bright comets, be extended over larger areas and in greater detail; leading, as in the case of the Sun, to a better understanding of their condition and constitution.

W. W. C.

REDISCOVERY OF MINOR PLANET (415) [1896 CO].

This planet was discovered February 7, 1896, by Professor MAX WOLF, at Heidelberg, Germany. At that time only a few observations were obtained, and it was not seen again until I picked it up by means of its trail upon a negative obtained with the Crocker telescope, October 2, 1899. From an examination of the times and places of opposition of the minor planets, given in the *Berliner Jahrbuch*, it appeared probable that the planet was new; and I accordingly made a series of observations of it with the twelve-inch telescope. From observations of October 4th, October 26th, and November 17th, I computed the following elements of its orbit:—

$$\begin{array}{rcl}
 \text{Epoch, 1899, October 4.5, Berlin mean time.} \\
 M = 332^{\circ} \ 37' \ 13''.1 \\
 \left. \begin{array}{l} \omega = 293 \ 31 \ 49 \ .5 \\ \Omega = 128 \ 13 \ 1 \ .7 \\ i = 8 \ 6 \ 28 \ .9 \end{array} \right\} 1899.0 \\
 \phi = 17 \ 34 \ 0 \ .7 \\
 \mu = 761''.2267 \\
 \log a = 0.445662
 \end{array}$$

When these elements were obtained, it was seen that they were more nearly like those which Dr. BERBERICH had obtained from the 1896 observations of (415) than those of any other planet. Yet the difference between the two systems of elements was so considerable that it still appeared probable that the planet which I had found was new. This, however, was not the case. Dr. PALISA, at Vienna, searched in vain for (415) in the place given by the ephemeris published in *Veröffentlichungen des Königlich-Astronomischen Rechen-Institute zu Berlin*, No. 10, and reported his failure in *Astronomische Nachrichten*, No. 3600. My elements were communicated to the *Astronomische Nachrichten*, and by means of them Dr. KREUTZ has proven the identity of the two supposedly different planets. By computing a place from these elements for February 11, 1896, Berlin mean midnight, he obtained a position in close agreement with an observation of (415) made at Vienna on that day. I have made this computation for the exact time of the Vienna observation, and find the difference between the observed and computed places to be as follows:—

$$\begin{array}{l}
 O - C: \Delta \alpha = + 20''.82 \\
 \Delta \delta = - 25''.1
 \end{array}$$

MT. HAMILTON, January 22, 1900.

E. F. CODDINGTON.

THE MEXICAN EARTHQUAKE OF JANUARY 19TH OBSERVED
AT THE LICK OBSERVATORY.

On the night of Friday, January 19th, the central part of Mexico was visited by a severe earthquake, which destroyed several lives, and did an immense amount of damage to buildings and other property.

This earthquake was observed at the Lick Observatory, some fifteen hundred miles from the region of greatest disturbance. At 10^h 50^m Mr. R. H. TUCKER, who was working with the meridian-circle, and had observed the transit of a star at 10^h 41^m, turned the telescope downward to the mercury-basin between the brick piers, for an observation of the nadir point. This, however, he found impossible. The mercury was oscillating from both north to south and east to west, with a period of about seven seconds. The full amplitude of the oscillation (doubled by reflection) could be estimated quite accurately by observing the excursion of the image of the cross-wires. It was very nearly 15". After about five minutes the oscillations began to decrease, and at 11^h 5^m had fallen to about one fourth of their maximum value. At 11^h 15^m they were still perceptible, but were no longer regular; the reflected image would come to rest for a few moments, and then continue to swing. At 11^h 30^m the vibration had so nearly ceased that the nadir observation was made. No change was found in the position of the instrument.

It will be seen that the oscillations continued for the remarkable length of time of forty minutes. There was no wind at the time, or anything to cause an unusual disturbance. A similar, though less marked, phenomenon on a previous occasion had been followed by an earthquake, though not a severe one, and Mr. TUCKER was led to expect a proportionally stronger shock after the oscillations he had observed on this night — an expectation which fortunately was not realized. It was not until January 22d that the news of the earthquake in Mexico reached Mt. Hamilton.

The thirty-six-inch refractor, the twelve-inch refractor, and the Crossley reflector were all in use, while the oscillations observed by Mr. TUCKER were in progress, but no disturbance of these instruments was noticed. It seems to me probable that there was a bodily motion of the whole surface of the ground, which would not produce an angular displacement of a telescope,

though it might cause the mercury to swing in the manner observed by Mr. TUCKER. No accurate data respecting the times of the most severe shocks in Mexico have yet been obtained.

J. E. K.

THE BINARY STAR, OΣ 341.

In 1898 I called attention to the change which had taken place in the relative positions of the components of this double star, and at the same time showed that the character of the motion proved it to be a binary system.

It will be remembered that the observations of this star from 1846 to 1886 gave no certain indications of motion, and, in consequence, that its components had come to be regarded as relatively fixed, at a distance of about $0''.40$. The observations of the past two years, however, show that the motion is quite rapid at times. During the first half of 1898, the star appeared perfectly round with the thirty-six-inch refractor, even when very high powers were used. On several occasions when the seeing was very fine, I failed utterly to detect any indication of duplicity, and Professor AITKEN had the same experience. In the latter part of the same year the distance had increased, and a very slight elongation could be seen, the measured distance being $0''.10$, and in another year it had increased to nearly $0''.20$. From this it would seem that this pair will soon become again a comparatively easy object for large telescopes under good conditions.

When an elongation was first detected in the latter part of 1898, I thought there had been a change of quadrant, but this has not been confirmed. The present position-angle differs very little from that obtained by all the earlier observers. An examination of all the observations available at the present time shows that in all probability the two stars are actually very near each other at periastron, and that the line of sight lies nearly in the plane of the orbit. From this it will be seen that the determination of the elements of the orbit of this binary, when sufficient observations for the purpose are obtained, will depend very largely upon the distances at the various epochs, and it is scarcely necessary to add that accurate measures of the distance at frequent intervals during the periods of rapid change such as the present will be particularly useful for this purpose.

January 17, 1900.

W. J. HUSSEY.

NEW MINOR PLANET 1899 EX.

I discovered this planet by means of its trail upon a negative taken with the Crocker telescope, October 2, 1899. At that time its brightness was estimated to be about 12th magnitude. I made a series of observations of it with the twelve-inch telescope, and from those of October 4th, 15th, and 26th, computed the elements of its orbit, as follows:—

Epoch, 1899, October 4.5, Berlin mean time.

$$\begin{array}{rcl} M = & 2^{\circ} & 43' & 11''.7 \\ \omega = & 79 & 36 & 27.4 \\ \Omega = & 293 & 10 & 50.2 \\ i = & 21 & 25 & 0.6 \\ \phi = & 11 & 50 & 32.5 \\ \mu = & 623'' & .873 & \end{array} \left. \vphantom{\begin{array}{l} M \\ \omega \\ \Omega \\ i \\ \phi \\ \mu \end{array}} \right\} 1899.0$$

$$\log a = 0.503274$$

E. F. CODDINGTON.

MT. HAMILTON, January 22, 1900.

THE SPECTROSCOPIC BINARY, β HERCULIS.

The velocity of β *Herculis* in the line of sight was found to be variable, in July, 1899, while measuring the third plate of this star's spectrum obtained with the Mills spectrograph. Three additional plates confirm the variation. Our observations up to date are as follows:—

1897, June 1, — 32^{km}

1898, June 13, — 31.9

1899, Feb. 26, — 23.3

July 31, — 30.9

Aug. 21, — 30.8

1900, Jan. 10, — 21.0

The period of revolution is undetermined, but it appears to be comparable to a year.

W. W. CAMPBELL.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to **SIDNEY D. TOWNLEY**, 2023 Bancroft Way, Berkeley, California.

The two astronomers whose portraits are published in this number were the recipients of the Bruce Medal of the Society in the years 1898 and 1899. Some account of the "distinguished services to astronomy" rendered by Professors **NEWCOMB** and **AUWERS** will be found in numbers 61 and 67 of these *Publications*.

The following special announcement, by President **WHEELER**, of the University of California, may be of interest to members of the Society residing in the neighborhood of Berkeley:—

"In connection with the course in Modern Astronomy—Astronomy I—the following lectures will be delivered during the second half of the current academic year by Director **JAMES E. KEELER**, Astronomer **W. W. CAMPBELL**, Astronomer **R. H. TUCKER**, and Astronomer **W. J. HUSSEY**, of the Lick Astronomical Department:—

Director **JAMES E. KEELER**:—

Tuesday, February 6th—The Theory and Construction of Reflecting Telescopes.

Thursday, February 8th—The Crossley Reflector and its Work.

Astronomer **W. W. CAMPBELL**:—

Tuesday, February 20th—Some Results Obtained from Measurements of Stellar Velocities in the Line of Sight.

Wednesday, February 21st, at 8 P. M.—The Lick Observatory Eclipse Expedition to India.

Astronomer **R. H. TUCKER**:—

Tuesday, February 27th—The Meridian Circle.

Thursday, March 1st—Star Catalogues.

Astronomer **W. J. HUSSEY**:—

Tuesday, March 6th, and Thursday, March 8th—Aspects of the Astronomy of Precision.

"Mr. **ALEXANDER MCADIE**, Honorary Lecturer on Meteorology in the University of California, and Local Forecast Official of the United States Weather Bureau in San Francisco, will deliver a series of four lectures on Meteorology, as a part of the course in Modern Astronomy. His subjects will be as follows:—

Tuesday, March 20th—At the Bottom of the Sea.

Thursday, March 22d—Lightning and Electricity of the Air.

Tuesday, March 27th—Exploring the Atmosphere.

Thursday, March 29th—Forecasting.

"Visitors will be welcome at all times. The lectures will be delivered at the regular hour of the course, 11:15 o'clock, except Professor **CAMPBELL**'s second one, in the new Astronomical Lecture-room of the Students' Observatory."

Professor **WM. HARKNESS**, Astronomical Director of the United States Naval Observatory, and Director of the Nautical

Almanac, has been retired after a service of nearly forty years in the Naval Observatory. His successors are Professor S. J. BROWN, as Director of the Naval Observatory, and Professor H. D. TODD, as Director of the Nautical Almanac. Professor BROWN is a graduate of the United States Naval Academy, and has been connected with the Naval Observatory about sixteen years, as Professor of Mathematics. Professor TODD, likewise Professor of Mathematics in the United States Navy, has been chief assistant in the Nautical Almanac Office for some years.

The Rumford Committee of the American Academy of Arts and Sciences, has appropriated the sum of \$500 to Professor E. B. FROST, of the Yerkes Observatory, to assist in the construction of a spectrograph especially designed for the measurement of stellar velocities in the line of sight.—*Science*, 1899, Nov. 17.

Mr. F. E. ROSS, last year Fellow in Astronomy in the University of California, has recently been appointed to the position of Instructor in Mathematics in the University of Nevada.

The library of the Society has lately received a copy of a new work, "Star-Names and Their Meanings," by RICHARD HINCKLEY ALLEN, a member of the Society. The work, published by G. E. STECHERT, New York, contains 547 pages, and presents a very neat appearance. Such a work must of necessity be incomplete, and is almost sure to contain some errors; still it also doubtless contains much that is good and valuable. In the introduction we find the following:—

"The world-wide field of research that I have endeavored to traverse, containing the records of four or five millenniums, it need hardly be said demands for its exploration the best efforts, long continued, of the scientist and scholar accomplished in archæology, astronomy, literature, and philology. None such, however, has appeared since IDELER's day, nearly a century ago; so that, with the desire of taking up again this most interesting task, and the hope of thus stimulating others more competent to carry it on, I have done what I could, although frankly confessing that I have fallen very far short of my ideal. Originality is not claimed for my book. Much of it has been gathered from widely scattered sources, brought together here for the first time in readily accessible form, although doubtless with errors and certainly with much omission; for while I have sought, as did MILTON's *Il Penseroso*, to

'sit and rightly spell
Of every star that heav'n doth show,'

yet in preparing my material I have seen, as Doctor SAMUEL JOHNSON wrote in the preface of his *Dictionary*,—

'that one enquiry only gave occasion to another, that book referred to book, that to search was not always to find; and to find was not always to be informed.'

So that, following him,—

'I set limits to my work, which would in time be ended though not completed.'

While to temper such criticism as may be bestowed upon my efforts, I quote again from the same source:—

'Dictionaries are like watches; the worst is better than none, and the best cannot be expected to go quite true.'

The work should certainly be in every library.

The report of the Board of Visitors of the United States Naval Observatory, extracts from which were printed in our last number, was transmitted to Congress by the Secretary of the Navy, and has now been printed in full as Senate Document No. 19. That the committee has thoroughly investigated the condition of the observatory; past as well as present, and spent a great deal of time on the report, is plainly evident. The majority of American astronomers will, we believe, heartily indorse the report of the board. Some criticisms might be made upon it; but if the recommendations there suggested are carried out, there can be but little doubt that the efficiency of the observatory will be largely increased. Its organization and government would then be similar to that of the great national observatories of Europe, which have rendered most valuable service to astronomy for many years. It is to be hoped that the proper legislation can be gotten through the present Congress.

Mr. Benjamin S. Mayhew has sent the following observations of November meteors, made at Olive, Winnipeg, Manitoba:—

1899.
 Nov. 13. 11 P.M. to 2 A.M. No meteors. Sky became overcast at 2 A.M.
 14. 11 P.M. to 2:30 A.M. No meteors seen. Sky overcast from 2:30 A.M.
 15. 11 P.M. till after midnight, when clouds came. No meteors seen.
 16. Cloudy.
 24. From 11 P.M., for several hours, meteors fell from all parts of the heavens in all directions, about eight every five minutes. Most of them were small; occasionally there was a brilliant one. For an hour before dawn they fell at about the same rate, and of similar appearance. (The shower of November 24th, above noted, was probably a portion of the *Bielid* shower from the radiant in *Andromeda*, which was reported by Professor YOUNG, as observed at Princeton.)

The following is an extract from a letter to Professor J. E. KEELER:—

"It may be of slight interest to you to know that the *Leonids* were carefully looked for by me during the nights November 13-16th. Unfortunately, they were totally overcast, except from 4 to 5 A.M., November 15th = 14^d 4^h 30^m to 5^h 30^m, G. M. T. (Lat. of ship being 11° S.; Long. 168½° E.). During this hour I counted about twenty shooting-stars in *Leo Major* and *Minor*, and next day (November 16th), from 4:30 to 5 A.M. = 15^d 4^h 40^m to 5^h 10^m, G. M. T. (Lat. 7½° S.; Long. 172° E.), I counted about fifteen shooting-stars, all from near γ *Leonis Majoris*, but was so disgusted with the weather that I took no notice of their paths.

FRANCIS J. BAYLDON, (2d Officer), S. S. *Warrimoo*.

December 4, 1899.

The *Astronomische Nachrichten*, Nos. 3606-3607, contains the definitive elements of the orbit of Comet 1894 IV (E. SWIFT) by one of the members of the Astronomical Society of the Pacific, Mr. FREDERICK H. SEARES. From a careful discussion of the seventy-five observations secured of this comet between the dates of November 21, 1894, and January 29, 1895, Mr. SEARES derives the following definitive elements:—

Epoch, 1894, Dec. 1.0. Osculation, 1894, Dec. 10.0.

$$\begin{array}{rcll} M_0 = & 8^\circ & 22' & 58''.2 \pm 4''.2 \\ \pi = & 345 & 23 & 11.1 \pm 4.4 \\ \Omega = & 48 & 48 & 23.4 \pm 27.7 \\ i = & 2 & 57 & 55.8 \pm 1.4 \\ \phi = & 34 & 51 & 37.3 \pm 7.1 \\ \mu = & 605''.9999 & \pm & 0''.0665 \end{array} \left. \vphantom{\begin{array}{l} M_0 \\ \pi \\ \Omega \\ i \\ \phi \end{array}} \right\} 1900.0$$

In his discussion, Mr. SEARES has given especial attention to the places of the comparison-star used. "Practically all of the existing catalogues were searched," and the adopted positions depend upon a careful consideration of the relative weights of these catalogues. The effect of *Jupiter*, *Saturn*, *Mars*, and the Earth upon the positions of the comet has also been fully taken into account.

Aside from the shortness of its period — a little less than six years — this comet is interesting to astronomers, from the fact that it may be identical with the lost comet of DE VICO — 1844 I. Mr. SEARES has undertaken the investigation of this question — the calculation of the definitive elements here noticed being the first part of the work.

As the comet returns to perihelion about August 20, 1900, a search ephemeris will be of great interest to those engaged in

the pursuit of comet-seeking, and we suppose that Mr. SEARES will publish such an ephemeris in the near future.

Some time ago a letter was addressed to the directors of the observatories of the Pacific Coast, asking for a statement of the work accomplished at each of these institutions during the year 1899. From the answers received, the following accounts have been written:—

CHABOT OBSERVATORY.—Being a part of the school system of the city of Oakland, this observatory is used chiefly for purposes of instruction. Two nights a week are set apart for classes from the schools, and special evenings are given to classes from schools and academies outside of the city. The observatory is open to the public two or three evenings of the week, and a time-service for the city of Oakland, is also maintained. Mr. BURCKHALTER writes, that all his spare time for several months in 1899 was spent in perfecting his apparatus for photographing the corona in the coming eclipse, which he expects to observe in Georgia. Experience at the Indian eclipse in 1898 showed some defects in the apparatus, but these have now been remedied, and Mr. BURCKHALTER thinks that the corona, weather permitting, cannot possibly get away from him next May.

LATITUDE OBSERVATORY.—Observations have been commenced at the Latitude Observatory, in Ukiah, but Dr SCHLESINGER reports slow progress, on account of bad weather. The first latitude observations were made on October 11th, and the following is a summary of the work accomplished from that date until the end of the year:—

1899.	Nights.	Pairs.
October	12	146
November	12	102
December	13	179
Totals	37	427

LICK OBSERVATORY.—Through the "Notices from the Lick Observatory," the readers of these *Publications* are kept pretty well informed concerning the work carried on in that institution. Director KEELER's report to the President of the University, for the year ending September 1, 1899, was printed in full in *Science*, November 10th, and is therefore not reprinted here. The report is very interesting, however, and the attention of the members of the Society is called to it. Concerning the nature and plan of the work of the observatory, we quote the following introductory remarks from Director KEELER's report: "The nature of the scientific work undertaken at the Lick Observatory is determined by such considerations as the unusually fine atmospheric conditions which prevail here, the nature of the instrumental equipment, and the number of observers on the staff. The general policy of the observatory is to carry on investigations which cannot be pursued to so great advantage elsewhere. Thus, comets which are bright enough to be

easily seen at the leading observatories receive only occasional attention, while comets which, by reason of their faintness or unfavorable position, are difficult of observation, are followed as closely as possible. Elaborate investigations, dealing with large masses of data, and requiring a large force of computers, can only be undertaken by richly endowed observatories or by those which receive Government assistance. The Lick Observatory makes the most of its natural advantages; and extended theoretical researches which can be made as well in a city as at a fine observing-station do not form a part of our general plan."

LOWE OBSERVATORY.—It is gratifying to note that Dr. SWIFT, Director of the Lowe Observatory, although afflicted with failing eyesight, has been able during the past year to add a comet and several nebulae to his long list of discoveries.

STUDENTS' OBSERVATORY.—The work at the Students' Observatory, Berkeley, is nearly all in the line of instruction, and the time of the members of the staff is given to directing and supervising the work of students rather than to research work. Professor LEUSCHNER, Director of the observatory, states that the Faculties of the University, in conjunction with the astronomers of the Lick Observatory, are now engaged in elaborating a comprehensive course of instruction, graduate as well as undergraduate, covering seven years, and leading to the degree of Doctor of Philosophy in three different lines,—Astronomy, Astrophysics, or Geodesy. A large part of the graduate work is to be done at Mt. Hamilton. We hope in a future number of these *Publications* to give a detailed account of the proposed plan. A new lecture-room has recently been added to the observatory, and this affords much needed room for accommodating the large classes in Modern Astronomy. The room is provided with every convenience for lantern-slide work, projecting spectra, etc. During the past year instruction was given in the following courses: Modern Astronomy, General Astronomy, History of Astronomy, Theoretical Astronomy, Method of Least Squares, Mechanical Quadratures, Interpolation and the Use of Tables, Graduate Course in Theoretical Astronomy, Graduate Course in Perturbations, and several courses in observatory work. During the term just past the total enrollment was 137, of whom eight were graduate students. The following may be mentioned among the special lines of work carried out by the students during the past year: Computation of the orbits of Comet 1898 VIII (CHASE) and Comet 1899 V (GIACOBINI); computation of the elements and the path of the shadow of the total solar eclipse for May 28, 1900; a determination, upon seven nights, of the difference of longitude between the Students' Observatory and the United States Coast and Geodetic Survey Observatory in San Francisco, including a least square reduction of the observations and also of all the previous determinations of longitude of the observatory.

UNITED STATES COAST AND GEODETIC SURVEY OBSERVATORY.—This observatory, situated in the Presidio Reservation, San Francisco, is used as a longitude base for the determination of new stations by telegraphic time-signals and for practice of observers. Captain AUG. F.

RODGERS, Assistant in Coast Survey, and in charge of the observatory, writes, however, that no new determinations were made during the past year.

From the *Comptes Rendus* of the 18th of December, 1899, we learn that the Lalande Prize, of 540 francs, has this year been awarded by the French Academy of Sciences to Mr. W. R. BROOKS for his record in the discovery of comets.

The Valz Prize, of 460 francs, has been awarded by the same body to M. NYRÉN, of the Pulkowa Observatory, for his work in the field of sidereal astronomy.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY, JANUARY 27,
1900, AT 7.30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 27, 1900.

MR. PAUL DANA *The Sun*, New York, N. Y.
MR. E. H. SHATTUCK Granby, Connecticut.
THE WOMAN'S COLLEGE Baltimore, Md.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD IN THE ROOMS OF THE
SOCIETY, JANUARY 27, 1900, AT 8 P. M.

Mr. BURCKHALTER presided. The minutes of the last meeting were read and approved.

The following papers were presented:—

1. Notes on the Zodiacal Light; being a summary of observations made at sea since 1889, by FRANCIS J. BAYLTON, R. N. R.
2. Planetary Phenomena for March and April, 1900, by MALCOLM MCNEILL.

A committee to nominate a list of eleven Directors, and Committee of Publication, to be voted for at the annual meeting to be held on March 1st, was appointed as follows: Messrs. CHAS. S. CUSHING, CHARLES ALTSCHUL, HENRY J. CROCKER, D. S. RICHARDSON, JOHN R. RUCKENELL.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed, as follows: Messrs. O. VON SIEDERN, F. H. McCONNELL, C. B. HILL.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. GEORGE C. PARDEE	Pres
Mr. JAMES E. KEELER	First Vice-Pres
Mr. CHARLES BURCKHALTER	Second Vice-Pres
Miss R. O'HALLORAN	Third Vice-Pres
Mr. C. D. PERRINE	Secret
Mr. F. R. ZIEL	
Mr. F. R. ZIEL	Treas

Board of Directors—Messrs. BURCKHALTER, CAMPBELL, HILL, KEELER, MOLESA,
O'HALLORAN, Messrs. PARDEE, PERRINE, PIERSON, VON GELDERN, ZIEL.

Finance Committee—Messrs. PIERSON, VON GELDERN, HILL.

Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.

Library Committee—Messrs. TOWNLEY, GEO. C. EDWARDS, Miss O'HALLORAN.

Committee on the Comet-Medal—Messrs. KEELER (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as long as possible. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Copies of the volumes for past years will also be supplied, to members only, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Non-resident members within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

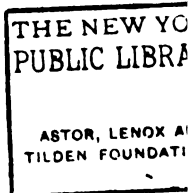
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco sends to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)





PUBLICATIONS
OF THE

Astronomical Society of the Pacific.

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ADDRESS OF THE RETIRING PRESIDENT OF THE
SOCIETY, IN AWARDING THE BRUCE MEDAL
TO H. M. ASTRONOMER, DR. DAVID GILL.

BY GEORGE C. PARDEE.

Following the custom established by my predecessors, it becomes my duty this evening to make public announcement of the award of the Bruce Gold Medal of the Society.

I take great pleasure in stating that the award for this year, by unanimous vote of the Board of Directors, was made to H. M. Astronomer at the Cape of Good Hope, Dr. DAVID GILL.

Before proceeding to give the Society an account of Dr. GILL's "distinguished services to astronomy," which so eminently entitle him to this mark of our consideration, it may not be inappropriate to call attention to the catholicity of science, and of astronomical science in particular, as exemplified in the first three awards of the Bruce Medal. Science recognizes no distinction of nationality; and while as Americans we are proud to think that an American astronomer was found worthy to be honored as our first medalist, we last year gladly recognized the right of the man who "to-day stands at the head of German astronomy" to take rank with him, and now make no less welcome the distinguished representative of English astronomy, whose work we honor to-night.

I am indebted to Professor R. G. AITKEN, of the Lick Observatory, for the collection and arrangement of the following facts concerning the astronomical work of our eminent medalist.

In a lecture delivered at the Royal Institution in 1884, Dr. GILL, after speaking of the fascination sidereal astronomy has ever had for the mind of man, of the questions without number that crowd upon the mind in contemplating the distances of space,

and of the little progress that has been made in the solution of these problems, used the following language :—

“Human knowledge in the slow developing phenomena of sidereal astronomy must be content to progress by the accumulating labors of successive generations of men; progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work.”

These few words may be taken as his scientific creed or confession of faith. Certainly his work forms a most significant commentary on its value. Born in Aberdeenshire, Scotland, in 1843, and educated at Aberdeen, he became Lord LINDSAY's assistant at the Dun Echt Observatory; and by him was sent to Mauritius, in 1874, to observe the transit of *Venus*. Dr. GILL took advantage of this opportunity to test practically his modification of the method of determining the value of the solar parallax from observations of a minor planet, first proposed by Dr. GALLE, of Breslau. Thus his first extensive piece of work was an important contribution to the determination of this fundamental constant of astronomy.

The next was the determination of the same constant from heliometer observations of the planet *Mars* at the opposition of 1877, a work for which the Royal Astronomical Society awarded him its gold medal in 1882. The last great piece of work published by him is his determination of this same constant from observations of the minor planets, *Iris*, *Victoria*, and *Sappho*, a work resulting in a value of this quantity which is generally admitted to be the most exact known, and one which, in all probability, will suffer but slight correction from future investigations. A better example of “concentrated systematic effort on a special thoughtfully selected problem” and of its “avail” it would be hard to find.

The efforts of astronomers to arrive at the value of the solar parallax, or its equivalent, the mean distance of the Earth from the Sun, form one of the most interesting chapters in the history of astronomy. From the earliest times it has engaged the minds of men; for a knowledge of it is necessary to give us any true conception of the actual dimensions of the solar system, of the masses and distances of the planets, and, ultimately, of the fixed stars. We cannot take time to recount the many solutions that

have been attempted of this "the noblest problem in astronomy," as Sir GEORGE AIRY describes it. We must content ourselves with quoting Dr. GILL's own remark, that "Every attempt has shown some short-coming in the previous one, and the result has always been to mark a new era of progress in the science, to create a fresh interest in its pursuit, and to stimulate the invention of more refined instruments and methods."

In 1867, NEWCOMB, from a discussion of all the available data, derived the value $8''.848$, corresponding to a distance of about 92,370,000 miles. This result was generally adopted by astronomers in their calculations, though no one was satisfied that it was sufficiently near the truth to make further investigation unnecessary. The question was, What method should be adopted to secure the most reliable result in the shortest time? Lord LINDSAY and Mr. GILL proposed to combine the suggestions of Dr. GALLE, of measuring the displacement of an asteroid among the stars at the time of opposition, with Sir GEORGE AIRY's, of employing what is now known as the diurnal method of observation, and to substitute the heliometer for the ordinary equatorial and micrometer.

The fact that *Juno*, one of the nearer asteroids, came to opposition at the time when they planned to be at Mauritius to observe the transit of *Venus* in 1874, seemed to offer a favorable opportunity to test the practical value of this new method. Owing to unfortunate delays in the arrival of the expedition at Mauritius, the series of observations was only one-third as extensive as had been planned, and, in consequence, the observers themselves did not "attach high importance to the value of the parallax deduced." The *important* result of this attempt was the high degree of precision which was found to attend the heliometer measures, confirming their previous conclusion, "that it is possible by means of the heliometer to determine the place of a minor planet relative to two stars (or if within a distance of 1000", to one star) with a probable error of less than $0''.01$." This led Dr. GILL to hope that the same method might be employed in observations on *Mars* at the very favorable opposition in 1877 with results of greater precision than could be attained by any other known method.

Through the liberality of Lord LINDSAY and several other members of the Royal Astronomical Society, and with the aid of grants from the Royal Society and from the Royal Astronom-

ical Society, Dr. GILL was enabled to take the heliometer used in the *Juno* observations, together with the necessary subsidiary instruments, to the island of Ascension to put his plan to the practical test. The method of observation was similar to that employed in the former attempt, with some modifications suggested by the experience then gained. It consisted, in brief, in observing the position of *Mars* with reference to selected stars as early after sunset in the evening and as late before sunrise in the morning as practicable, thus measuring double the parallax displacement of the planet. The accuracy attainable in these measures is so great that it was desirable to have the positions of the comparison-stars fixed with all possible precision. To this end these stars were carefully reobserved at thirteen of the principal observatories of the world.

The final result of this admirable piece of work was to fix the value of the solar parallax at $8''.78 \pm 0''.012$. At the time, this ranked as one of the best determinations of this constant that had been made, and, as we have said, the work won for its author the gold medal of the Royal Astronomical Society. But in his memoir, Dr. GILL himself showed that the result might be subject to a possible small correction from difficulties peculiar to observations of *Mars*, and again stated with emphasis that the most promising method to insure an accurate result was by the heliometric observation of such of the minor planets as approached nearest to the Earth.

The exceptionally favorable oppositions of *Iris* in 1888, and of *Victoria* and *Sappho* in 1889, afforded an excellent opportunity to repeat the observation, and by that time, too, a number of very powerful heliometers had been constructed, several of them possessing refinements of adjustment planned by Dr. GILL himself. Having secured assurances of co-operation in the observations from a number of heliometer observers,—especially from Dr. ELKIN, of Yale, and from Dr. AUWERS, of Berlin,—Dr. GILL issued a carefully planned programme of work which made provision for “the complete determination and elimination of every conceivable form of systematic error.” This was fully carried out; concerted observations of the three asteroids were made at the Cape of Good Hope, in the southern hemisphere, and at New Haven, Göttingen, Leipzig, Bamberg, and Oxford, in the northern; the comparison-stars were carefully reobserved on the meridian-circles of the principal observatories of the world; and

the whole mass of material reduced and discussed with every refinement of method known to modern astronomy.

It is difficult to form an adequate conception of the amount of labor involved in such a piece of work. Aside from the careful observations of the phenomena themselves, thousands of observations most trying to the eyes are necessary to determine with accuracy the errors of the instruments, (Dr. GILL, for example, made about fifty thousand observations, the equivalent of nine months' work at two hours a day, to determine the division-errors of the scales of his heliometer,) and when the observation material is at last all collected, the real work may be said to have just begun. To handle such an enormous mass of data, to subject it to the minute and detailed analysis necessary to eliminate all possible forms of error, to reduce it to a manageable set of normal equations, and, finally, to determine the most probable values of the quantities sought, demands not only mathematical judgment and skill of the highest order, but also patient tenacity of purpose and a tremendous capacity for work.

While the determination of the definitive positions of the comparison-stars from the meridian-circle observations was due to Dr. AUWERS, and the discussion of the results for *Iris* to Dr. ELKIN, the plan of the entire work was Dr. GILL'S. He discussed the results for *Victoria* and *Sappho*, made the final revision of the work, and is responsible for the result. His conclusion is that the value of the solar parallax from these observations is $8''.802$, with a probable error of $\pm 0''.005$, and that this may be regarded as absolutely reliable within such limits as are indicated by the value of its probable error. This means that the distance from the Earth to the Sun is known to within about fifty or sixty thousand miles. Or, to illustrate the accuracy of the result in another way, the outstanding error may be represented by the angle subtended by a foot-rule at a distance of a little over seven thousand miles.

It must not be supposed that Dr. GILL'S entire time has been devoted to investigations of the solar parallax. Although his work in this connection has been sufficient to insure him a very high rank among astronomers, it has been far from completely engrossing his attention. On his appointment as H. M. Astronomer at the Cape of Good Hope in 1879, Dr. GILL took with him the heliometer used in his observations of *Juno* and *Mars*, and, in the years 1881-83, instituted a series of observa-

tions to determine the value of the annual parallax of nine of the more interesting southern stars. In this work he had the assistance of Dr. ELKIN, who was his guest during those years. "These investigations constitute the first successful attempt made by extra-meridian observations, to determine stellar parallax in the southern hemisphere." The results for the nine stars measured are accepted generally by astronomers. This work has been, and is being, continued with the new heliometer, by Dr. GILL and other observers under his direction, the "great cosmical questions to be answered" being "not so much what is the precise parallax of this or that particular star, but (1) what are the average parallaxes of those of the first, second, third, and fourth magnitude, respectively, compared with those of lesser magnitude? (2) what connection does there subsist between the parallax of a star and the amount and direction of its proper motion? or can it be proved that there is such a connection or relation? From such data we should probably be able to determine the law of absorption of star-light in space, and be provided with the facts at present wanting for determining with more precision the amount and direction of the motion of the solar system in space." A second memoir on this subject, giving the parallaxes of thirteen additional stars, is now nearly completed.

While work in these two allied fields of research may be regarded as the more important of Dr. GILL's personal contributions to the advancement of astronomy, we must not fail to call attention to the great services he has rendered in the past twenty-one years as Director of the Observatory at the Cape of Good Hope, and to the important enterprises he has inaugurated or been intimately associated with. Struck with the splendor of the great comet of 1882, he secured, with the aid of a local photographer, several photographs of it. The number and sharp definition of the star-images on these plates led him to suggest the use of photography for star-charting in general, and in particular for extending the Bonn Durchmusterung from -23° to the South Pole. Without reviewing the history of the movement that led finally to the assembling of the Astrophotographic Congress and its decision to photograph the entire heavens on a uniform system, we may note that Dr. GILL took an important part in all the proceedings; and that the Cape Observatory has practically completed the series of photographs needed in the

zone from -40° to -52° Declination. The work of measuring up these plates is now in progress under Dr. GILL's supervision and on engines built from his designs.

But before the Astrophotographic Congress met, Dr. GILL had decided to carry out his idea of a photographic Durchmusterung of the heavens south of -23° Declination; and by the year 1889 the necessary plates had all been taken—in considerable part at his private expense. Professor KAPTEYN, of Gröningen, volunteered to undertake the labor of measuring these plates, the pressure of other work making it impossible to measure them at the Cape Observatory. Two volumes of this great work, containing the places and magnitudes of more than 316,000 stars between -19° and -52° Declination, have already been distributed, and the third, which will complete the work, is nearly ready.

Of the ordinary administrative duties pertaining to a position such as Dr. GILL holds, we need here say nothing more than that the building up of a great observatory (and such the one at the Cape of Good Hope has become under his direction) would of itself be a task sufficient for a life-work. When we add that in addition to all else, Dr. GILL has found time to design the instruments and methods employed in the geodetic survey of South Africa, to plan and control the field operations, and personally to superintend and take part in the measurement of several of the base-lines, we are obliged to admire his capacity for work almost as much as his ability as an observer and a mathematician.

This brief sketch, imperfect as it is, will, I think, serve to show that Dr. GILL's services to astronomy have been amply adequate to entitle him to the highest honor we can bestow upon him,—the award of the Bruce Gold Medal.

Mr. Secretary, in the absence of our medalist, I hand the award to you, to transmit to Dr. GILL, with the assurances of the heartiest wishes of this Society that his future labors may be rewarded with the distinguished success that has crowned them in the past.

March 31, 1900.

ASTRONOMICAL OBSERVATIONS IN 1899.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

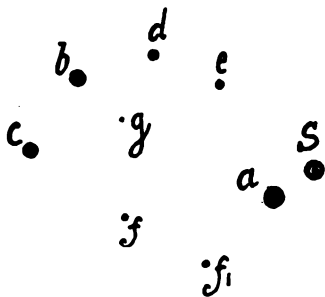
VARIABLE STARS.

*Z Cygni.**

January	5:	Z almost invisible.	August	5:	< e.
				13:	id.
February	5:	invisible.	September	13:	invisible.
March	30:	id.		24:	id.
April	17:	= e.	October	25:	id.
May	6:	a little < c.	November	20:	id.
	28:	{ < a.	December	3:	id.
		{ > b.		22:	= e.
				30:	a little < d.

S Ursæ majoris.

January	5:	S a little < e.	August	13:	a little < e.
	13:	id.		26:	= f i.
	17:	{ < e.		31:	a little < f i.
		{ > f i.	September	4:	= f.
February	5:	= f i.		9:	id.
	10:	id.		12:	id.
	14:	almost = g.		24:	= g.
March	10:	< g.	October	4:	id.
	30:	almost = g.		8:	< g.
April	2:	id.		25:	id.
	12:	id.	November	20:	= g.
	22:	= f i.	December	3:	a little < f i.
April	28:	> f i.		22:	{ > f i.
		< e.			{ < e.
August	5:	= e.		30:	a little < e.



a	=	6.5	Mag.
b	=	7.0	
c	=	7.2	
d	=	8.5	
e	=	9.2	
f	=	10.0	
g	=	10.2	
h	=	10.3	

0 ————— 30'

* Vide the sketch in the *Publications A. S. P.*, No. 48, page 69.

*T Ursæ majoris.**

January	5:	= e.	August	31:	= d.
	17:	= g.	September	4:	a little < d.
February	5:	a little < g.		9:	id.
	10:	< g.		12:	{ < d.
	14:	id.			{ > e.
March	10:	invisible.		24:	{ < e.
	30:	extremely faint.			{ > f.
April	2:	id.	October	8:	= f.
	12:	invisible.		25:	< g.
	22:	id.	November	20:	invisible.
	28:	id.	December	3:	id.
August	5:	= a.		22:	extremely faint.
	13:	almost = b.		30:	invisible.
	26:	= c.			

W Pegasi.†

January	5:	W < g.	September	9:	{ < c.
February	5:	id.			{ > d.
	10:	faint.		12:	a little > d.
May	6:	a little > f.		13:	id.
August	5:	{ < b.		24:	a little < e.
		{ > c.	October	4:	a little > f.
	13:	a little > c.		7:	id.
	14:	{ > c.		8:	id.
		{ < b.		25:	= g.
	26:	a little < c.	November	9:	id.
	31:	id.		20:	< g.
September	4:	< c.	December	22:	invisible.
				31:	id.

The Star BD, 20°, 1083.

January	6:	{ Star < b.	April	2:	{ almost = c.
		{ > c.			{ not > c.
February	6:	id.	December	3:	= b.
	10:	= c.		31:	{ = c.
	14:	id.			{ < b.

The variations were in this year only between the limits: 8.2 and 8.5 mag.

* *Vide* the sketch in the *Publications A. S. P.*, No. 22, page 63.

† *Vide* the sketch in the *Publications A. S. P.*, No. 60, page 23.

SHOOTING STARS.

No.	Time.			Beginning.		End.		Mag.	Note.
1	Aug. 9,	h 10	m 7	s 0	P.M.	216 + 38	224 + 22	2	Train.
2			13	0		292 + 65	259 + 58	2	
3			14	0		201 + 61	191 + 60	4	
4			16	30		129 + 68	153 + 62	3	Light undulations.
5			17	0		34 + 57	120 + 64	3	
6			24	30		256 + 12	257 — 1	3	
7			24	40		355 + 13	351 + 10	3	Train.
8			28	30		317 + 39	297 + 25	3	
9			38	30		193 + 55	180 + 54	3	
10			42	45		11 + 76	346 + 81	2	Train.
11			46	30		353 + 45	353 + 33	1	
12			55	30		277 + 68	252 + 55	2	
13			58	15		3 + 39	347 + 31	3	Train.
14	11		0	0		297 + 77	297 + 57	3	
15			2	0		357 + 19	350 + 14	2	
16			2	5		305 — 6	302 — 11	2	Train.
17			3	0		191 + 65	198 + 50	3	
18			6	30		309 + 46	330 + 62	2	
19			10	0		334 + 48	324 + 44	2	Train.
20			14	0		242 + 21	245 + 10	2	
21			16	30		200 + 75	217 + 57	1	
22			19	0		175 + 51	187 + 38	1	Train.
23			23	45		252 + 25	247 + 7	1	
24			26	50		332 + 36	317 + 30	3	
25			28	30		289 + 8	285 — 5	2	Train.
26			32	0		23 + 23	18 + 7	1	
27			43	0		34 + 56	17 + 54	2	
28			49	0		275 + 40	258 + 18	1	Train.
29			49	5		300 + 16	294 + 4	1	Train.
30			51	30		259 + 30	259 + 13	1	Train.
31			51	45		326 + 36	312 + 17	2½	Yellow train.
32			52	30		270 + 50	280 + 41	2	
33			56	15		295 + 10	288 + 23	1	
34	Aug. 10,	12	0	15	A.M.	236 + 70	217 + 53	2	Train.
35	Aug. 11,	10	20	0	P.M.	144 + 55	160 + 46	2	
36			22	30		170 + 53	183 + 45	2	
37			31	0		253 + 32	250 + 18	2	Train.
38			35	0		318 + 56	296 + 46	2	
39			37	0		287 + 50	277 + 34	1	
40			42	0		342 + 34	333 + 19	2	Train.
41			44	0		350 + 62	310 + 66	1	Train.
42			46	0		360 + 89	232 + 76	1	Train.
43			49	0		145 + 75	183 + 62	2	Train.
44			57	30		339 + 13	352 + 18	2	Slow.
45	11		2	30		339 + 13	15 + 8	2½	Nebulous.

No.	Time.	Beginning.	End.	Mag.	Note.
46	Aug. 12, 10 ^h 5 ^m 45 ^s	339 + 13	77 + 61	1	
47	9 0	215 + 80	218 + 64	2	Train.
48	17 45	327 + 38	312 + 27	3	Train.
49	20 45	330 + 17	332 + 6	3	Fast.
50	23 45	120 + 73	162 + 70	3	
51	26 0	129 + 61	163 + 52	2	Train.
52	27 30	129 + 61	324 + 37	3	
53	32 0	312 + 12	316 + 5	1	
54	34 0	173 + 65	192 + 53	1	Train.
55	35 0	348 + 43	360 + 28	2	
56	36 30	317 + 45	317 + 37	3	
57	51 30	304 + 48	302 + 35	3	
58	52 10	338 + 8	333 - 1	2	
59	55 0	38 + 46	28 + 35	1	Train.
60	56 0	179 + 52	184 + 45	1	
61	11 0 40	358 + 21	350 + 12	2	Train.
62	1 30	228 + 43	224 + 28	2	Train.
63	1 35	233 + 42	224 + 24	2	
64	2 30	293 + 12	283 + 5	2	
65	2 45	271 + 33	258 + 26	1	Train.
66	5 40	271 + 33	295 - 21	1	
67	7 15	355 + 3	350 - 8	1	Train.
68	9 30	224 + 39	222 + 25	3	Train.
69	12 20	327 + 17	318 + 4	4	
70	14 30	170 + 78	181 + 62	3	Train.
71	15 10	290 + 8	284 - 3	1	Train.
72	17 0	91 + 41	92 + 34	1	Train, fast.
73	27 30	252 + 28	247 + 11	3	
74	32 30	260 + 62	210 + 52	3	
75	35 0	122 + 59	140 + 53	1	
76	35 30	122 + 59	311 + 23	1	
77	43 30	335 + 35	352 + 44	2	Streak, slow.
78	43 40	267 + 30	277 + 6	1	Train.
79	46 45	197 + 47	200 + 38	1	Train.
80	49 0	265 + 7	265 - 6	1	Train.
81	51 0	330 + 53	330 + 38	♀	Train.
82	57 10	10 + 41	358 + 33	2	Streak.
83	Aug. 13, 12 1 0 A.M.	315 + 27	302 + 15	1	Train.

No. 8. This meteor was also observed at Copenhagen : $232^{\circ} + 38^{\circ} \rightarrow 226^{\circ} + 21^{\circ}$ (2).

No. 13. Was also observed at Copenhagen : $216^{\circ} + 47^{\circ} \rightarrow 223^{\circ} + 2^{\circ}$ (2).

No. 21. End point observed at Copenhagen : $208^{\circ} + 32^{\circ}$ (3).

No. 81. Was observed at Copenhagen : $237^{\circ} + 33^{\circ} \rightarrow 230^{\circ} + 7^{\circ}$ (2).

The four meteors named have given the following results:—

No.	Beginning.			End.			Real Length of the Path.	Observer.
	<i>h</i>	λ	ϕ	<i>h</i>	λ	ϕ		
8	116	⁰ 1 43	⁰ 55 43	87	⁰ 2 15	⁰ 55 31	50	{ TORVALD KÖHL. OTTO ASMUSSEN. TORVALD KÖHL. OTTO ASMUSSEN. TORVALD KÖHL. OTTO ASMUSSEN. TORVALD KÖHL. OTTO ASMUSSEN.
13	76	⁰ 1 13	⁰ 56 3	66	⁰ 1 31	⁰ 55 51	31	
21	...	...	...	109	⁰ 3 40	⁰ 56 34	..	
81	92	⁰ 2 11	⁰ 55 57	42	⁰ 2 16	⁰ 55 50	51	

* * * *h* and β are expressed in kilometers; λ is W. long. from Copenhagen; ϕ is N. lat.; *h* is the altitude of the meteor above the Earth's surface. Odder is situated in 2° 25' W. long. from Copenhagen and 55° 58' N. lat.

Only a few *Leonids* were seen in the period, November 13–16. The following meteors were observed here:—

No.	Time.			Beginning.	End.	Mag.	Note.	
1	Nov. 15,	^h 5	^m 14	^s 0 A.M.	⁰ 156 + 27	⁰ 170 + 52	♀	Train, yellow.
2					⁰ 172 + 5	⁰ 176 — 1	2	
3					⁰ 163 + 27	⁰ 178 + 30	4	
4					⁰ 156 — 8	⁰ 170 — 13	1	
5					⁰ 175 + 45	⁰ 206 + 58	1	
6					⁰ 160 + 15	⁰ 166 + 4	3	
7					⁰ 170 + 13	⁰ 170 + 26	4	
8					⁰ 120 + 34	⁰ 128 + 12	1	
9					⁰ 139 + 27	⁰ 124 + 35	2	
10					⁰ 152 + 50	⁰ 153 + 71	1	
11				⁰ 185 — 5	⁰ 187 — 8	1		
12				⁰ 206 + 25	⁰ 219 + 20	2		
13				⁰ 103 — 13	⁰ 99 — 14	4		
14				⁰ 172 + 17	⁰ 177 + 17	4		
15				⁰ 135 + 3	⁰ 129 — 7	2		
16	Nov. 16,				⁰ 184 + 1	⁰ 191 — 7	3	Train, fast.
17					⁰ 190 + 28	⁰ 203 + 26	1	
18					⁰ 142 + 27	⁰ 135 + 34	2	
19					⁰ 160 + 25	⁰ 175 + 29	3	
20					⁰ 128 + 23	⁰ 113 + 20	2	
21					⁰ 181 + 12	⁰ 189 + 9	♀	Train, yellow.
22					⁰ 157 + 27	⁰ 166 + 32	2	
23					⁰ 165 + 8	⁰ 172 + 1	3	Train, yellow.
24					⁰ 144 + 7	⁰ 142 — 4	♀	

On the 30th and 31st of July the author made a public trial of FOUCAULT'S pendulum experiment in the Museum of Art of

the Danish State at Copenhagen. The pendulum had a length of 17 meters, and weighed 35 kilogrammes. After an hour had elapsed the pendulum had just passed the twelfth degree of the circle accordant to the calculated deviation.

VISUAL OBSERVATIONS OF THE MOON AND PLANETS,
MADE AT HARVARD COLLEGE
OBSERVATORY.*

BY EDWARD S. HOLDEN.

The volumes of the Harvard Observatory *Annals* are printed with a commendable promptness that adds greatly to their usefulness. Most of them deal with technical matters of no great immediate general interest. The two volumes noticed contain several chapters, however, on the changes observed in the surface of the Moon, on the planets, etc., that are especially interesting to all intelligent people, and for this reason, it is here attempted to give some account of their contents. As many of the results attained are novel, it is, first of all, sought to present them with sufficient fullness. This is not the place for a discussion as to the evidence upon which they rest.

Volume XXXII of the *Annals* contains a chapter upon the surface conditions and the rotation of the planet *Mercury*, the diameter and atmosphere of *Venus*, and the surfaces of *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. The discussion of the observations of *Mars* is reserved for another volume. The observations of *Mercury* are illustrated by sixteen sketches by two observers (W. H. PICKERING and DOUGLAS) of the excessively faint surface markings. Mr. PICKERING's conclusions from these drawings are that no rotation of the markings was noticeable between July 14, and August 5, 1892, a period of twenty-two days, or one quarter of the period of revolution of the planet in its orbit, and that the period of rotation of the planet on its axis and revolution in its orbit must coincide, as was announced by SCHIAPARELLI in 1879. It is, in fact, not unlikely that the two

* *Annals of the Astronomical Observatory of Harvard College.* EDWARD C. PICKERING, Director. Vol. XXXII, Part II. Visual Observations of the Moon and Planets, by WILLIAM H. PICKERING, Assistant Professor of Astronomy in the Observatory, Cambridge, 1900, 4to, and *ibid.* Vol. XXXIII. Miscellaneous researches made during the years 1894-99. Cambridge, 1900, 4to.

periods do coincide, but the observations here given present little evidence to prove it. The drawings of the two observers, P. and D., differ on July 22d at 8^h, agree very well at 10^h, differ widely on July 23d at 6^h, agree fairly on July 23d at 9^h. But the drawings last mentioned should agree with the pair made at 10^h of the day previous to prove the point at issue, whereas there is little, if any, resemblance; and there is no agreement at all in the extremes of the series July 14th and August 5th. The observations in question are excessively difficult to make, but those that have been secured are not, it would seem, adequate. Mr. PICKERING concludes that the atmosphere of this planet is very rare, and that the hemisphere turned towards the Sun is very likely incandescent, while the temperature of the central regions of its opposite hemisphere is much lower than that of our Arctic regions. A curious distribution of matter would thus take place on the surface, through a process of fractional distillation. The hemisphere that is perpetually illuminated by the Sun would be composed of substances of high boiling points, while the other hemisphere would be composed only of those of very low boiling points. It is not likely, we may add, that a planet subject to such conditions can sustain human life.

The diameter of the planet *Venus* was determined to be 7,662 miles. In its size, as well as in certain other respects, it is not unlike our Earth. Measures of the horizontal refraction of the atmosphere of *Venus* give 93', which is much greater than previous results. If, as is probable, the surface of *Venus* seen by us, is no more than the outer layers of its clouds, it follows that at the planet's real surface its atmosphere is many times denser than our own. We may add here, that there is no proof that *Venus* is unfit for human habitation.

"The most important discovery relating to *Jupiter*," Mr. PICKERING says, "was in regard to the nature of the material forming its belts. As had been previously surmised, they were found to lie above the white, dense, cloudy surface of the planet; but what was perhaps unexpected, was the fact that the appearance was not due to large dense masses of cloud, but to numerous very minute, isolated cloudlets." A very good photograph of *Jupiter*, and an excellent photograph of *Saturn*, are reproduced in the plates.

The diameter of the planet *Neptune* was determined to be 31,000 miles, and its disk was found to be decidedly darker at the

edge than at the center, thus proving the existence of a deep atmosphere. *Jupiter, Saturn, Uranus, and Neptune* are, it may be added, alike in this respect. All of them have extensive atmospheres, but little is known of the constitution of their envelopes, and next to nothing of the condition of their solid or liquid nuclei. It is likely that all of them are at a high temperature.

SWIFT's comet of 1892 was the subject of investigation by photography and otherwise. Some of the photographs are reproduced in the volume, and they are extremely interesting. Those of the inner portions of the tail seem to show that the comet was rotating on an axis passing longitudinally from the head through the tail in a period of about four days. Mr. PICKERING points out that there is an *a priori* reason for such a rotation. "In the light of the connection between sun-spots and terrestrial electric disturbances, it may be assumed that the Sun can be looked upon as an enormous electro-magnet, surrounded by an equatorial electric current. If now, the tail of a comet is due to electrically charged gaseous matter receding from the nucleus, we shall have a series of electric currents radiating from the nucleus like spokes upon the hub of a wheel, and bending backwards to form the tail. If the Sun and comet are electrified, as we have supposed, the jets and envelopes of the comet, carrying with them the tail, must rotate as we have described."

As the earth has a gaseous envelope, like a comet, and as it is subject to electric action from the Sun, the question arises whether something analogous to a comet's tail is not to be found on the Earth. Mr. PICKERING finds the analogy in the high auroras. "All the observations of high auroras are located along a line such as would be cut upon the surface of the Earth by a cylindrical tail 7,200 miles in diameter, whose axis passed through the center of the Earth and pointed directly away from the Sun." In diameter, length, direction, and time of formation, the aurora is shown to resemble the tail of a comet, and it appears likely that the secular auroral period has its analogue in the world of comets. Mr. PICKERING's prediction is, that if a comet comes in view of the Earth during a year of great sun-spot activity, it is more likely to have a large and fine tail than if it arrives during a year of slight activity. Such a theory as this might, it would seem, be tested by the appearances of ENCKE's periodic comet.

The following paragraph is quoted as a brief explanation of the phenomena of comets expressed in a simple form :—

"The head of a comet seems therefore to be merely a meteor-swarm containing so much gaseous material that when electrified by its approach to the Sun, it will be rendered luminous. When the gases, by successive discharge and loss into space, have become too rare to be rendered visible in this manner, the object, if discovered, is known simply as a meteor-swarm. Each meteor in the comet's head, when remote from the Sun, is surrounded by its own individual atmosphere of hydrocarbons, etc., in a solid condition. When this atmosphere is sufficiently warmed by the Sun's rays to evaporate, it becomes sufficiently electrified to partially overcome the slight force of gravity of the meteors, and a portion of it escapes and unites with that of other meteors to form the tail. Thus, if the meteors and their atmospheres are sufficiently widely separated from each other, the comet may be brilliant and yet transparent at the same time."

No space remains to speak in detail of other interesting researches in these volumes. Long-continued observations on the Moon prove the existence of changes on its surface, of vegetation, of a slight atmosphere, according to Mr. PICKERING. As many of his conclusions are in the nature of discoveries, they will not pass unchallenged, and it is not difficult to point out paragraphs where more evidence is very desirable. At the same time, it is only just to say that the treatment of all the topics in the volume is suggestive, and thus very valuable, though it is often inconclusive, being based on too slight and easily accepted foundations. Volume XXXIII is devoted to miscellaneous researches on the brightness of certain asteroids, on the Gegenschein and Zodiacal Light (by Professor SEARLE), on Variable Stars, Nebulæ, Comets, Satellites, etc. Taken together, the volumes contain results of long-continued and faithful work, intelligently directed.

THE CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, MAY 28, 1900.

BY CHARLES BURCKHALTER.

The preparations for the expedition from this Observatory to observe the eclipse of May 28th next, at the expense of one of our members,—Mr. JOHN DOLBEER, of San Francisco,—are nearly completed. The Pierson eclipse telescope, with the Pardee lens attached, making two telescopes of four-inch aperture and fifteen feet focal length, is ready for shipment, and will be forwarded in a few days, to insure arrival in ample time.

The Southern Pacific Company and its connections, by the kindness of General Traffic Manager WILLIAM SPROULE, has granted less than half-rate for transportation of instruments. The station will be at or near Union Point, Georgia, and a leading man of the place, WILLIAM HART, Esq., has already placed me under obligations for valuable information and offers of help.

As the geographical position of the village is uncertain by as much as three miles or more, it will be necessary to observe for position—especially for latitude—before “establishing” the station. I expect to start in time to make the preliminary observations and be ready for actual installation of instruments by May 1st, which will give me ample but not unnecessary time for complete preparation. I have already received offers of volunteer assistance from Mr. HART and others, and I feel confident that I shall be in good hands, and it will be a real comfort, after the experiences of the last two expeditions, to be in a country where it will not be necessary to talk either through an interpreter or with my hands and feet.

In working out the controlling diaphragms, the exposure times are computed for each minute from 16' to 30' (counting from Sun's center), and thereafter for each two minutes, intermediate places giving intermediate times.

In the partial table below, the exposures are given for each minute from 16' to 20'; then at four-minute intervals, from 20' to 40', and thereafter at ten-minute intervals, except at 75' and 76', where numbers 1, 3, 7, and 9 end. It will be observed that numbers 2 and 8 apparently stop at 50' and 60'. Both of these, however, end at 95'; but, as they are experimental, they are not given in full.

Number 4 is Secretary ZIEL's ideal exposure, after a study of the India negatives of the Pierson expedition. This curve I expect to be one of the very best, especially as I intend to bring him this plate and others for expert development. Number 8 is my own ideal, and may be said to be a “middle-of-the-road” exposure out to 64'.

The exposures will be made in pairs, five for each telescope, the times of each pair being identical, as the exposures begin and end simultaneously by electrical apparatus.

I shall use Cramer crown plates, and have entire confidence that the times indicated in the table cannot be far wrong, and that at least one plate will be nearly perfectly exposed. I am

especially confident that the time given at the Moon's edge is too much, rather than too little, and if I find at the end of the programme that I can make an additional exposure of two seconds, I have a diaphragm prepared that will give only 0^s.01 at the Moon's edge in a two seconds exposure.

The exposures given below can be made with great exactness, probably within two or three per cent. This is especially true for the extreme inner corona. For example, if number 6 should receive a total exposure of only 8^s instead of 10^s, as proposed, the exposure at 16' would be only 0^s.04 instead of 0^s.05. As the exposures are made by moving a lever to the right and left, engaging electrical contacts, they can be made with nearly the same precision as recording the transit of a star on the chronograph.

PROPOSED EXPOSURES, MAY 28, 1900.

Order of Exposure	No.	1	2	3	4	5	6	7	8	9	10
		^s	^s	^s	^s	^s	^s	^s	^s	^s	^s
Exposure at Moon's Limb		0.02	0.04	0.10	0.06	10.00	0.05	0.08	0.05	0.12	0.06
Total Exposure.		4.00	4.00	8.00	8.00	10.00	10.00	8.00	8.00	6.00	6.00
Exposure Counting from		^s	^s	^s	^s	^s	^s	^s	^s	^s	^s
Center of Sun ... at 16'		0.02	0.04	0.10	0.06	10.00	0.05	0.08	0.05	0.12	0.06
17		.04	.06	.16	.09		.12	.11	.10	.14	.08
18		.08	.10	.24	.14		.18	.18	.15	.18	.12
19		.12	.16	.36	.20		.29	.26	.22	.23	.18
20		.18	.22	.50	.27		.41	.35	.30	.30	.25
24		.42	.56	1.70	.55		1.00	.86	.73	.76	.62
28		.78	1.06	3.22	.94		1.72	1.58	1.40	1.72	1.16
32		1.21	1.70	4.56	1.48		2.20	2.42	2.18	3.14	1.96
36		1.62	2.31	5.34	2.10		2.60	3.16	3.00	4.00	2.80
40		2.00	2.85	5.90	2.85		3.00	3.83	4.00	4.50	3.42
50		2.83	3.65	6.73	4.30		4.00	5.08	6.38	5.17	4.41
60		3.52	...	7.36	5.40		5.00	6.25	7.50	5.56	5.02
70		3.96	...	7.84	6.20		6.00	7.41	...	5.87	5.50
75		3.99	...	8.00	...		...	8.00	...	6.00	...
76		4.00	...	...	...		...	...	...	...	...
80		...	...	...	6.90		7.00	...	...	...	5.84
90		...	...	...	7.50		8.00	...	...	...	6.00
95		...	...	...	...		...	...	...	...	...
100		...	...	...	8.00		9.00	...	...	...	...
110		...	...	...	...	10.00	10.00	...	...	...	...

CHABOT OBSERVATORY, Oakland, Cal., March 10, 1900.

SOME COMPUTATIONS RELATIVE TO THE SOLAR ECLIPSE OF MAY 28, 1900.

By S. C. PHIPPS.

While studying the theory of eclipses in the course in advanced practical astronomy under Dr. TOWNLEY, some computations were made for the eclipse of May 28, 1900.

Starting with the data given in the *American Ephemeris*, the elements of the eclipse, rising and setting limits, maximum in the horizon, northern and southern limits, curve of central eclipse, and northern and southern limits of the total eclipse, were computed according to the methods given in CHAUVENET'S "Spherical and Practical Astronomy." In most cases the results agree exactly with those printed in the *Ephemeris*, the greatest difference being one tenth of a minute in some of the latitudes and longitudes. About three fourths of the above work was also computed by Mr. B. A. BAIRD.

The circumstances of the eclipse for Mr. BURCKHALTER'S station near Union Point, Georgia, (latitude $33^{\circ} 36'$ north, and longitude $83^{\circ} 3'.2$ west,) were computed, giving the following results:—

Local Mean Time (Ast.)		
Beginning of eclipse.....	May 27th, 19 ^h 00 ^m 57 ^s	
End of eclipse	21 26 34	
Duration of eclipse	2 25 37	
Beginning of total eclipse .	20 8 16	
End of total eclipse.....	20 9 40	
Duration of total eclipse..	1 24	
	First Contact.	Fourth Contact.
Position-angle,	$256^{\circ} 32'.2$	$76^{\circ} 33'.4$

The position-angle is measured from the north point of the Sun's image toward the east.

The eclipse will be seen as a partial one in California, and in the neighborhood of San Francisco the eclipse will begin before sunrise. I have computed the circumstances of the eclipse for the Student's Observatory, Berkeley, (latitude $37^{\circ} 52'.4$ north, longitude $122^{\circ} 15'.5$ west,) and for the Davidson Observatory, San Francisco, (latitude $37^{\circ} 47'.5$ north, longitude $122^{\circ} 25' 7$ west,) giving the following results:—

*Maximum of eclipse:*Berkeley, May 28th, 5^h 37^m 35^s A. M., P. S. T.San Francisco, May 28th, 5^h 37^m 31^s A. M., P. S. T.*End of eclipse:*Berkeley, May 28th, 6^h 27^m 40^s A. M., P. S. T.San Francisco, May 28th, 6^h 27^m 36^s A. M., P. S. T.*Greatest obscuration:*

Berkeley, 0.5104.

San Francisco, 0.5107.

Position-angle of fourth contact:

Berkeley, 107° 46'.3

San Francisco, 107° 46'.1.

The amount of obscuration indicates that the Moon will cover a little more than half the Sun's diameter.

STUDENTS' OBSERVATORY,

UNIVERSITY OF CALIFORNIA, March 23, 1900.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1900.

BY MALCOLM MCNEILL.

MAY.

Eclipse.—There will be a total eclipse of the Sun on the morning of May 28th. The total eclipse begins at sunrise in the Pacific off the coast of Mexico, and the line of totality crosses the United States from Louisiana to Virginia; thence crossing the Atlantic to Spain; thence through Spain and North Africa to Egypt, where it ends at sunset. Unfortunately, the duration of totality is short — less than two minutes from any land station where it can be seen. It will be visible as a partial eclipse throughout the United States.

Mercury is a morning star until May 29th, when it passes superior conjunction and becomes an evening star, but is not far enough away from the Sun to be easily visible at any time during the month.

Venus having passed greatest east elongation in April, has now begun to approach the Sun, and the distance lessens about 5° during the month; the interval also between sunset and the

setting of the planet shortens from about four to about three hours. It moves westward among the stars about 26° during the month, to a point in *Gemini* a few degrees south of *Castor* and *Pollux*. It reaches greatest brilliancy about the end of the month, and throughout the month will be bright enough to be seen in full daylight in clear weather.

Mars is increasing its apparent distance from the Sun, and by the end of the month rises about an hour and a half before sunrise, so that it may be seen in the early morning twilight under good weather conditions; but it will not be at all conspicuous.

Jupiter rises earlier, before sunset, toward the close of the month, and is getting into good position for evening observation. It is in opposition with the Sun on May 27th. It moves westward about 4° in the constellation *Scorpio*, and on May 31st is in almost the same position it held on January 26th.

Saturn rises at about 9 P.M. on May 31st. It moves westward about 2° in *Sagittarius* during the month, and at the end of the month it is in about the same position it occupied at the end of February. It is following in its retrograde motion even more closely than did *Jupiter* the path it marked out during its forward (or eastward) motion. Sometimes the retrograde motion of these planets is along a path which makes quite a loop with the forward motion.

Uranus is still near *Jupiter*, but rather farther away than during April. By the end of the month it is 5° east and $1^{\circ} 38'$ south of *Jupiter*. It moves a little more than 1° westward during the month in the constellation *Scorpio*.

Neptune is still in the extreme eastern part of *Taurus*, near *Gemini*, and moves about 1° eastward during the month.

JUNE.

Eclipse.—There will be a partial eclipse of the Moon on the night of June 12–13th, visible throughout the United States. The fraction of the Moon's diameter which will be obscured is only 0.001, so that it is a very partial eclipse indeed, and will scarcely be detected without careful instrumental measurement. Naked-eye observations will hardly be able to detect anything unusual about the Moon. However, the eclipse is perhaps interesting from the fact that its occurrence is all that saves the year 1900 from having the minimum possible number of eclipses

— two of the Sun (there will be another eclipse of the Sun in November), as happened in 1886, and will happen again in 1904.

The Sun is at its solstice, and summer begins June 21st, 1 P.M., P. S. T.

Mercury is an evening star throughout the month, and after the first week of the month remains above the horizon an hour or more after sunset. At the end of the month the interval is more than an hour and a half. It is, therefore, in very good position for evening observation. On June 13th it passes only 3' south of the third magnitude star ϵ *Geminorum*. The time of nearest approach occurs during daylight in this country, and the motion of the planet will cause the apparent distance to be about equal to the Moon's diameter by the time the stars become visible in the evening.

Venus is an evening star, but is rapidly approaching the Sun, so that the interval between sunset and the setting of the planet shortens from three hours, on June 1st, to about half an hour, on June 30th. It moves eastward about 4° among the stars until June 15th, and then moves westward about the same amount, but all the time moving southward, so that it does not retrace its course by several degrees.

Mars rises an hour earlier than during May, and moves 22° east and 6° north through *Aries* into *Taurus*. Towards the end of the month it is about 5° south of the *Pleiades*, and will be an easy object to see, although not conspicuous.

Jupiter is well up at sunset, and remains above the horizon until nearly morning. It moves 3° westward and a little north in the constellation *Scorpio*, and at the end of the month is less than half a degree east and south of β *Scorpii*.

Saturn is above the horizon practically the entire night, and comes to opposition with the Sun on June 23d. It moves about 2° westward in *Sagittarius*, and is just north of the Dipper handle in that constellation. There is a close conjunction of *Saturn* and the Moon on the evening of June 13th, close enough for an occultation in some parts of the world. As seen in the telescope, the apparent breadth of the rings is just about as it was during the opposition of 1899, very near the maximum.

Uranus is still in the neighborhood of *Jupiter*, a little farther away than during May, the average distance being about 6° east and 2° south.

Neptune is moving slowly eastward in the extreme eastern part of *Taurus*.

MAY-JUNE, 1900.

PHASES OF THE MOON, P. S. T.

			H.	M.	
First Quarter,	May	6,	5	39	A.M.
Full Moon,	May	14,	7	37	
Last Quarter,	May	21,	12	31	P.M.
New Moon,	May	28,	6	50	A.M.
First Quarter,	June	4,	10	59	P.M.
Full Moon,	June	12,	7	38	
Last Quarter,	June	19,	4	57	
New Moon,	June	26,	5	27	

THE SUN.

1900	R. A.	Declination.	Rises.	Transits.	Sets.
	H. M.	° '	H. M.	H. M.	H. M.
May 1,	2 33	+ 15 1	5 5 A.M.	11 57 A.M.	6 49 P.M.
11,	3 11	+ 17 50	4 53	11 56	6 59
21,	3 51	+ 20 9	4 44	11 56	7 8
June 1,	4 36	+ 22 2	4 39	11 58	7 17
11,	5 17	+ 23 5	4 36	11 59	7 19
21,	5 58	+ 23 27	4 36	12 1 P.M.	7 26.
July 1,	6 40	+ 23 8	4 40	12 4	7 28

MERCURY.

May 1,	1 1	+ 3 25	4 14 A.M.	10 25 A.M.	4 36 P.M.
11,	1 58	+ 9 36	4 10	10 43	5 16
21,	3 10	+ 16 44	4 17	11 15	6 13
June 1,	4 47	+ 23 20	4 45	12 9 P.M.	7 33
11,	6 18	+ 25 20	5 27	1 1	8 35
21,	7 35	+ 23 27	6 13	1 38	9 3
July 1,	8 30	+ 19 31	6 44	1 53	9 2

VENUS.

May 1,	5 43	+ 26 51	7 26 A.M.	3 7 P.M.	10 48 P.M.
11,	6 23	+ 26 53	7 27	3 8	10 49
21,	6 58	+ 26 6	7 27	3 4	10 41
June 1,	7 28	+ 24 33	7 19	2 49	10 19
11,	7 42	+ 22 48	7 2	2 24	9 46
21,	7 42	+ 20 59	6 29	1 44	8 59
July 1,	7 25	+ 19 18	5 40	12 48	7 56

MARS.

May 1,	1 8	+	6 17	4 11 A.M.	10 32 A.M.	4 53 P.M.
11,	1 36	+	9 12	3 49	10 21	4 53
21,	2 4	+	11 55	3 29	10 10	4 51
June 1,	2 36	+	14 41	3 7	9 58	4 49
11,	3 5	+	16 56	2 48	9 47	4 46
21,	3 34	+	18 53	2 30	9 37	4 44
July 1,	4 4	+	20 32	2 14	9 27	4 40

JUPITER.

May 1,	16 30	—	20 55	9 11 P.M.	1 56 A.M.	6 41 A.M.
June 1,	16 15	—	20 21	6 47	11 34 P.M.	4 21
July 1,	16 1	—	19 49	4 33	9 23	2 13

SATURN.

May 1,	18 21	—	22 20	11 7 P.M.	3 46 A.M.	8 25 A.M.
June 1,	18 14	—	22 24	8 59	1 38	6 17
July 1,	18 5	—	22 28	6 48	11 27 P.M.	4 6

URANUS.

May 1,	16 41	—	22 9	9 26 P.M.	2 6 A.M.	6 46 A.M.
June 1,	16 36	—	21 59	7 14	11 55 P.M.	4 36
July 1,	16 31	—	21 49	5 10	9 52	2 34

NEPTUNE.

May 1,	5 39	+	22 9	7 46 A.M.	3 6 P.M.	10 26 P.M.
June 1,	5 43	+	22 12	5 45	1 5	8 25
July 1,	5 48	+	22 14	3 52	11 12 A.M.	6 32

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope to May 27th, then off right.)

		H.	M.			H.	M.
I, D,	May 5,	8	27 P.M.	III, R,	June 1,	12	52 A.M.
I, D,	8,	12	41 A.M.	I, R,	1,	9	28 P.M.
I, D,	9,	7	9 P.M.	II, R,	6,	10	32
I, D,	15,	2	34 A.M.	I, R,	8,	11	22
I, D,	16,	9	3 P.M.	I, R,	10,	5	50
II, D,	20,	1	37 A.M.	II, R,	14,	1	9 A.M.
I, D,	21,	4	28	I, R,	16,	1	16
I, D,	24,	12	57	I, R,	24,	9	39 P.M.
III, D,	24,	7	8 P.M.				
I, D,	25,	5	25				
II, D,	27,	4	13 A.M.				
II, R,	30,	7	56 P.M.				
I, R,	31,	2	59 A.M.				



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

USE OF THE CROSSLEY REFLECTOR FOR PHOTOGRAPHIC MEASUREMENTS OF POSITION.

Although the observation of asteroids is not intended to be a regular part of the work of the Lick Observatory, a good many observations of these bodies have been made here during the past year. All the Watson asteroids have been observed for the National Academy of Sciences, and in the course of this work a number of new asteroids have been discovered and regularly observed.

It sometimes happens that an asteroid cannot be found readily with visual or with small photographic telescopes. It may be situated in the Milky Way, where the number of stars is confusing, or it may be faint or moving very slowly. If found, there may be no catalogue-stars near enough to it for purposes of comparison.

In such cases the Crossley reflector has furnished a convenient means for both finding the asteroid and determining its position. The method of observation is as follows: The field having been identified by means of a DM. chart, an exposure of half an hour is given to the photographic plate, in the usual manner. The slide is then closed, the guiding eye-piece of the double-slide plate-holder is slipped along two or three hundredths of an inch and again clamped, and the guiding-star is brought to the new position of the cross-wires. Another exposure of (say) two minutes is then given, the times of beginning and end being accurately noted. Finally, the slide is partly drawn, the driving-clock stopped, and stars are allowed to trail over the lower third of the plate for several minutes.

On the resulting negative, all the star-images are double. The stronger images serve for purposes of identification, and the

* Lick Astronomical Department of the University of California.

weaker images for exact measurement. The diameter of the smallest star-discs should not exceed $1''.5$ or $2''.0$. The corresponding images of the asteroid are respectively a trail, and an image which is not distinguishable from a disc, and which, in the subsequent measurement of the plate, is referred to the short-exposure images of the stars. The trails serve for the accurate orientation of the plate.

On a photograph of the asteroid (439) *Ohio*, made on the night of December 27, 1899, and measured by Mr. CODDINGTON, there are eleven catalogue-stars. The mean position of the asteroid, at the mean time of exposure, $13^h 10^m 35^s$ P. S. T., is R. A. = $7^h 27^m 42^s.221$; Decl. = $-6^\circ 9' 26''.79$.

Comparison of the mean with the individual measures gives the following residuals (Mean - Obs.):

Comparison-Star.	Residual, R. A.	Residual, Decl.
DM. — $5^0 2165$	— $0''.068$	— $0''.56$
— 6 2167	— 0.054	+ 0.73
— 6 2162	— 0.030	+ 0.68
— 6 2184	+ 0.056	+ 0.56
— 6 2166	+ 0.064	— 0.97
— 6 2153	+ 0.039	— 0.27
— 6 2156	+ 0.003	+ 0.44
— 6 2158	— 0.056	— 0.07
— 6 2146	+ 0.025	+ 0.31
— 6 2150	— 0.038	+ 0.04
— 6 2185	— 0.051	— 0.90

The probable error of the mean is, therefore, in R. A. $\pm 0''.010$; in Decl. $\pm 0''.12$. It will be seen that this result is comparable with the best measurement by visual methods, J. E. K.

THE CROCKER-LICK OBSERVATORY ECLIPSE EXPEDITION.

By the generosity of Mr. WILLIAM H. CROCKER, of San Francisco, the Lick Observatory will be able to send a party to Georgia, to observe the total solar eclipse of May 28th. Only two observers, Messrs. W. W. CAMPBELL and C. D. PERRINE, will be sent out from the Observatory; but several European astronomers have expressed a desire to join the party, and similar requests have also been received from astronomers connected with American colleges which do not intend to send out expeditions of their own.

I take this opportunity to acknowledge the indebtedness of the Lick Observatory to Mr. CROCKER for his generous assist-

ance. It is especially gratifying to the members of the Observatory staff that this practical token of appreciation and confidence comes from a life member of the Astronomical Society of the Pacific, and a prominent citizen of our own State.

The instrumental equipment of the expedition will be quite complete. The principal instrument for photographing the corona will be the five-inch telescope of forty feet focal length, used by the Lick Observatory parties in South America and India. For photographing the corona on a smaller scale there will be several cameras of from five to six inches aperture and others of smaller size. One slit spectrograph, and two objective spectrographs, arranged to give a continuous record of the changing spectrum at the beginning and end of totality, are also included in the equipment. Observations of contacts will be made.

Any observers having experience in astronomical or physical work, who wish to join the party at their own expense, like the gentlemen referred to farther above, are invited to communicate with the Director of the Lick Observatory before April 20th, and after that date with Professor W. W. CAMPBELL, Lick Observatory Eclipse Expedition, Atlanta, Georgia.

JAMES E. KEELER.

ELEMENTS OF COMET *a* 1900 (GIACOBINI).

This comet was discovered by GIACOBINI at Nice, on January 1st, the position of discovery being R. A. $2^h 57^m 44^s$, Decl. $-7^\circ 55'$. The first accurate position received at the Lick Observatory was that of February 3d, obtained by JAVELLE at Nice. After the receipt of the announcement of discovery the weather at Mount Hamilton was stormy, and only cleared when the Moon was too near the comet's place to warrant a search. The first observation obtained here was on February 16th, and the next on the 21st. From these three observations I have deduced the following parabolic elements:—

$$\begin{array}{l} T = 1900, \text{ April } 29.0781, \text{ G. M. T.} \\ \left. \begin{array}{l} \omega = 24^\circ \quad 36' \quad 56''.6 \\ \Omega = 40 \quad 24 \quad 38.8 \\ i = 146 \quad 25 \quad 22.2 \end{array} \right\} 1900.0 \\ \log q = 0.123476 \end{array}$$

Residuals Obs. — Comp.

$$\begin{array}{rcl} \Delta \lambda' \cos \beta' & & - 0''.4 \\ \Delta \beta' & & + 0.1 \end{array}$$

An ephemeris from these elements shows that the comet will continue to move slowly west and north for the next four months. On July 1st its position will be $\alpha = 23^h 40^m$; $\delta = +42^\circ$; and on August 1st, $\alpha = 19^h 33^m$; $\delta = +41^\circ$. It will probably be invisible from the latter part of the present month until the end of May, owing to its proximity to the Sun. The comet is rather faint, being estimated as between the 10th and 11th magnitudes. It is nearly round, about 2' in diameter, and has a faint nucleus.

MT. HAMILTON, March 2, 1900.

C. D. PERRINE.

ASTRONOMICAL TELEGRAMS.

(Translations.)

Professor J. E. KEELER, CAMBRIDGE, Mass., Feb. 1, 1900.
Lick Observatory: (Received 1:03 P.M.)

Kiel cables that a comet was discovered by GIACOBINI at Nice on Jan. 31^d. 292 G. M. T. in R. A. $2^h 57^m 44^s$; Decl. $-7^\circ 55'$. The position is only approximate.

(Signed) EDWARD C. PICKERING.

Professor JAMES E. KEELER, BOSTON, Mass., Feb. 2, 1900.
Lick Observatory: (Received 5 P. M. Feb. 4.)

Kiel cables that faint Comet *a* was observed at Nice by JAVELLE on Feb. 3^d. 2893 G. M. T. in R. A. $2^h 49^m 51^s.0$; Decl. $-6^\circ 40' 10''$. Daily motion in R. A. 39° W.; in Decl. $25'$ N.

(Signed) E. C. PICKERING.

CAMBRIDGE, Mass.,

To Professor JAMES E. KEELER, Feb. 21, 1900.
Lick Observatory: (Received 12:50 P.M.)

Kiel cables that Comet *a* was observed by JAVELLE at Nice on Feb. 17^d. 3148 G. M. T. in R. A. $2^h 22^m 2^s.8$; Decl. $-1^\circ 19' 27''$. There is some error in the cablegram, for the control word does not check.

(Signed) E. C. PICKERING.

LICK OBSERVATORY, Feb. 26, 1900.

To Harvard College Observatory: (Sent 10:20 A.M.)

Elements and ephemeris of Comet *a* have been computed by PERRINE as follows:

T = April 29^d.08 G. M. T.

$\omega = 24^\circ 37'$
 $\Omega = 40 25$
 $i = 146 25$ } Equinox of 1900.0
 $q = 1.3289$

(Signed) JAMES E. KEELER.

[The ephemeris is here omitted.]

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Professor GEORGE E. HALE, Director of the Yerkes Observatory; Professor K. F. KÜSTNER, Director of the University Observatory of Bonn; Professor ROBERT HELMERT, Director of the Prussian Geodetic Institute; and Dr. JUAN M. THOME, Director of the National Observatory of the Argentine Republic, have recently been elected foreign members of the Royal Astronomical Society.

M. POINCARÉ has been awarded the gold medal of the Royal Astronomical Society.—*Science*, February 9th.

The Directors of the Benjamin Apthorp Gould Fund announce that they are prepared to make another distribution of the income of the fund. The money is given to aid in carrying out special astronomical investigations. Applications should be sent to Dr. S. C. CHANDLER or Professor ASAPH HALL, Cambridge, or to Professor LEWIS BOSS, Albany.

Science, February 23, 1900, states that the Trustees of the Western University of Pennsylvania have decided to begin the erection of the new building for the Allegheny Observatory. It will be situated in Riverview Park, and will cost \$250,000.

The American Academy of Arts and Sciences has recently given \$500 from the income of the Rumford fund to Harvard College Observatory, to carry out an investigation of the brightness of faint stars.

A bill has been introduced in Congress to provide for the reorganization of the Naval Observatory along lines suggested in the report of the Board of Visitors.

Dr. W. S. EICHELBERGER, for some time computer in the Nautical Almanac Office and the Naval Observatory, has been appointed Professor of Mathematics in the United States Navy and stationed for duty at the Naval Observatory.

Señor JULIO GARAVITO, Director of the Bogota Observatory, has printed a small pamphlet in which he describes the determination of the latitude of the observatory by a modification of TALCOTT's method. The instrument used was a two-inch field theodolite.

The modification of TALCOTT's method consists in setting the horizontal thread a little below the meridian altitude of the lowest star, and noting the interval between the transits of each star over the same thread, before and after the meridian passage. The observations are afterwards reduced to the meridian altitude in the usual manner. No micrometer is required. The rate of the timepiece is important, but not the actual correction; and as all the observations are made at the same altitude, there are no corrections for differential refraction. The level attached to the vertical circle is used for determining variations of inclination.

With respect to accuracy, the observations are quite satisfactory, the probable error of a determination from one pair of stars being $\pm 1''.5$. The writer modestly describes himself as "hardly more than a lover of astronomy," and regards the results of his method as being therefore all the more satisfactory. Carrying out the individual observations to $0''.001$ is, however, about the only evidence of unfamiliarity with practical astronomical work.

It would seem that the principal advantage of Señor GARAVITO's method is, that it requires no micrometer, so that it can be applied to any altitude and azimuth instrument. With respect to precision it cannot be regarded as any improvement on the ordinary method, since the greatest source of inaccuracy — the uncertainty of the level indications — remains unchanged.

The *Astronomical Journal* for February 12th contains a very suggestive article by Professor SIMON NEWCOMB, on the distribution of the mean motions of the minor planets. Astronomical students looking for a subject of a doctor's thesis might do well to look at it.

In *Nature* for January 4th and 11th there is a very interesting article by Sir NORMAN LOCKYER describing the eclipse expedition to Viziadurg, in January, 1898.

The *Astrophysical Journal* for January contains a valuable article on eclipse problems by Professor GEORGE E. HALE.

No one who intends to make observations at the coming eclipse should fail to read it.

In a number of illustrations which have recently appeared, the great telescope now under construction for the Paris Exposition of 1900 is represented as projecting views of heavenly bodies upon a screen in a darkened room, where they are viewed by a large audience; and an article in *Nature* (December 21, 1899) states that "an image of the Moon 16 meters in diameter, and of *Mars* 3.70 meters in diameter, are promised to the *abonnés*."

If such promises have actually been made, it would seem to be worth while for somebody to point out in advance their utter absurdity, since the daily press will certainly attribute them to astronomers. The area of the image of *Mars*, as above stated, is 8.8 times the area of the object-glass (1.25 meters diameter) through which all the light in the image must pass, and this number represents the ratio of illumination of object-glass and screen. In other words, the screen will be only about one-ninth as bright as a sheet of paper placed outdoors, where *Mars* (and no other source of light) can shine on it. The image on the screen will be further dimmed by loss of light in the apparatus; but whether it is a few dozen or score of times brighter or fainter makes little difference, as it will be equally invisible under all these circumstances.

The eye-end of the telescope will be large enough to hold a magic lantern, with which fine views of the heavenly bodies could be projected on the screen, and the telescope would then be independent of the weather. Possibly this is what is meant in the promises to subscribers.

HENRY HOLT & Co. have recently issued a new elementary astronomy by Dr. E. S. HOLDEN. From a hasty examination it seems that the work of both the author and the publishers has been well done. The material is well arranged, and the cuts and figures, of which there are many, are for the most part excellent. One exception to the last statement may be found in figure 207, the Moon passing near the *Pleiades*. The figure of the crescent Moon extends considerably beyond a semicircle, the terminator is the arc of a circle instead of an ellipse, three stars are within the horns of the Moon, and the crescent has an impossible position with reference to the stars of the cluster.

In discussing the double canals of *Mars* Dr. HOLDEN offers

an explanation not before given in any text-book. On page 310 we find the following:—

“Marvels of ingenious speculation have been printed to explain why ‘intelligent inhabitants’ having one ‘canal’ not sufficient for ‘commerce’ did not widen it, but preferred to dig another parallel to it, and why this second ‘canal’ sometimes vanishes altogether in ‘a few hours.’ Recent experiments have proved that these companion canals are optical illusions produced by fatigue of the eye and by bad focusing. Some, at least, of the single narrow dark streaks (‘canals’) have a real existence. It is probable that many of those laid down and named on the maps of SCHIAPARELLI, LOWELL, and others are mere illusions. It is likely that all the double canals were so.”

We do not know the nature of the experiments to which Dr. HOLDEN refers; but we believe that the idea that many of the markings supposed to have been seen on *Mars*, *Venus*, and *Mercury* are optical illusions of some nature has steadily gained ground for some time. Any adequate explanation of these peculiar markings will be welcomed by astronomers.

The Harvard College Observatory intends to search for an intermercurial planet by means of photography during the total eclipse of the Sun on May 28th. Four lenses, each having an aperture of five inches and a focal length of eleven feet four inches, “will be placed on one mounting, in such a manner as to photograph a region extending for sixteen degrees on either side of the Sun, and a breadth of ten degrees throughout its length.” From experiments recently made at Cambridge, Professor PICKERING is led to believe that all stars brighter than the eighth magnitude which are in the region about the Sun will make a sensible impression on the photographic plate during the total phase of the eclipse.

Within the past few weeks the astronomical world has lost by death two well known observers and two generous friends. Dr. CARL THEODOR ROBERT LUTHER, for many years Director of the Düsseldorf Observatory, was well known for his work on the minor planets; Dr. GEORGE RÜMKER, Emeritus Director of the Hamburg Observatory, was recognized as an able observer of comets and asteroids, and, in addition, was known for the attention he gave to all questions relating to the improvement of navigation.

Mr. LEANDER J. McCORMICK, who died recently in Chicago at the age of eighty-one, will be remembered by astronomers for

his generous gift to the University of Virginia of the splendid 26-inch Clark refractor and of the observatory in which it is housed.

Members of this Society will experience in common with astronomers the world over a personal sense of loss in learning of the death of Miss CATHARINE WOLFE BRUCE. From the *Astrophysical Journal* for March we quote the following paragraph:—

“For years confined to her room by an ever-increasing illness, and personally known by but few of the many who have benefited by her bounty, Miss BRUCE has nevertheless endeared herself to men of science at home and abroad, aiding as perhaps no other has done the progress of research. Recognizing no national boundaries, giving assistance where it was most needed, and seeking no fame for herself, Miss BRUCE may well be regarded as one of the most sympathetic and generous patrons astronomy has ever known. Many a project, which without her assistance would have come to naught, has been successfully developed through her aid. Many an advance in our knowledge of the heavens is due directly to the help she gave. The appeals that came to her from far and wide were received with the kindest consideration, both by herself and also by her sister, Miss M. W. BRUCE, who often acted in her stead. Astronomers in almost every country of the civilized world know from their own experience how prompt was the response and how often it took the affirmative form. In common with many others who have received less direct advantage from her gifts to science, they will sincerely mourn her loss.”

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF
DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE
PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON
SATURDAY, NOVEMBER 25, 1899, AT 2 P.M.

Mr. BURCKHALTER presided. A quorum was present.

The purpose of the meeting being the Third Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present :—

SAN FRANCISCO, November 25, 1899.

THIRD AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at 2 o'clock P.M., for the purpose of awarding the medal for the year 1900; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

DAVID GILL,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: CHAS. BURCKHALTER W. W. CAMPBELL (by proxy),
CHAS. B. HILL (by proxy), JAMES E. KEELER (by proxy),
E. J. MOLERA, ROSE O'HALLORAN, GEO. C. PARDEE (by proxy),
C. D. PERRINE, WM. M. PIERSON, OTTO VON GELDERN (by proxy), F. R. ZIEL.

Adjourned.

In answer to a letter addressed to Dr. GILL, notifying him of the action taken by the Directors, the following letter of acceptance was received :—

ROYAL OBSERVATORY, CAPE OF GOOD HOPE,
January 11, 1900.

F. R. ZIEL, Esq., *Secretary Astronomical Society of the Pacific* :

My Dear Sir: I have the honour to acknowledge receipt of your letter dated 1st January, 1900, stating that your Board of Directors has awarded to me the Third Bruce Gold Medal of the Astronomical Society of the Pacific.

Permit me in reply to express the gratification which the acceptance of this medal affords me, because of the distinguished names of the previous laureates, the excellent Statutes which regulate its bestowal, and the unanimous character of the award.

Above all, I value this medal as indicative of good will and kindly feeling on part of American Astronomers towards me,—feelings which, believe me, I most sincerely reciprocate.

Yours very sincerely,

Signed: DAVID GILL.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 31, 1900, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 31, 1900.

Dr. G. DEL AMO 1705 Bush St., S. F., Cal.
Mr. ARTHUR ROYDEN MERRITT . . } 432 West 16th St., New York
City, N. Y.

The Library Committee presented its report as follows, and the report was, on motion, adopted and filed:—

To the Board of Directors of the Astronomical Society of the Pacific:

We, the undersigned Committee on the Society's Library, report as follows :—
During the past year 74 volumes, not including unbound books and pamphlets, have been added to the shelves of the library by gift, purchase, and binding. The total number of volumes in the library, as shown by the accessions book, is 1,116.

The Committee wishes to call the attention of the Directors to the crowded condition of the shelves, and of the drawers for pamphlets. Relief must be provided soon.

The following is an account of the expenditures from the Alexander Montgomery Library Fund for the year ending March 31, 1900:—

1899, June 12.	<i>Astronomical Journal</i> , Vol. I	\$ 9 00
Dec. 5.	Petty expenses	1 75
1900, Feb. 9.	Subscription to <i>Popular Astronomy</i> ..	2 50
Mar. 6.	Hicks-Judd Co., for binding	37 70
	Total	\$50 95

Respectfully submitted,

SIDNEY D. TOWNLEY, *Librarian*.
ROSE O'HALLORAN.

The following resolution was, on motion, adopted:—

WHEREAS, The Russian Astronomical Society is desirous of obtaining a copy of the Donohoe Comet-Medal, be it

Resolved, That one of the unengraved medals belonging to the Society is herewith presented to the Russian Astronomical Society.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL
SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE
SOCIETY, MARCH 31, 1900, AT 8 P. M.

The meeting was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented :—

1. Address of the retiring President of the Society in Conferring the Bruce Medal upon Dr. DAVID GILL, by GEORGE C. PARDEE.
2. Reports of Committees: on Nominations; on the Comet Medal; on Auditing; and Annual Report of the Treasurer.
3. Astronomical Observations in 1899, by TORVALD KÖHL.
4. The Chabot Observatory—Dolbeer Eclipse Expedition, May 28, 1900, by CHAS. BURCKHALTER.
5. Planetary Phenomena for May and June, 1900, by MALCOLM MCNEILL.
6. Visual Observations of the Moon and Planets made at Harvard College Observatory, by EDWARD S. HOLDEN.
7. Some Computations relative to the Solar Eclipse of May 28, 1900, by S. C. PHIPPS.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. CHAS. BURCKHALTER, W. W. CAMPBELL, JOHN DOLBEER, C. B. HILL, JAMES E. KEELER, E. J. MOLERA, Miss R. O'HALLORAN, Messrs. C. D. PERRINE, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN, S. D. TOWNLEY, O. VON GELDERN.

Messrs. TOWNLEY and McCONNELL were appointed as tellers. The polls were open from 8:15 to 9 P. M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED
MARCH 31, 1900.

This report relates to the calendar year 1899. The comets of 1899 have been:

- Comet *a* (unexpected comet), discovered by Dr. LEWIS SWIFT, Director of the Lowe Observatory, on March 3d.
- Comet *b*, TUTTLE's periodic comet, re-discovered by Professor MAX WOLF, at Heidelberg, on March 5th.
- Comet *c*, TEMPEL's second periodic comet, re-discovered by Mr. C. D. PERRINE, Assistant Astronomer in the Lick Observatory, on May 6th.
- Comet *d*, HOLMES's periodic comet, re-discovered by Mr. C. D. PERRINE, Assistant Astronomer in the Lick Observatory, on June 10th.
- Comet *e* (unexpected comet), discovered by M. MICHEL GIACOBINI, at the Nice Observatory, on September 29th.

The Comet-Medal has been awarded to the discoverers of Comets *a* and *e*, in accordance with the regulations.

Respectfully submitted,

JAMES E. KEELER,
WM. M. PIERSON,
CHAS. BURCKHALTER.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE
FISCAL YEAR ENDING MARCH 31, 1900.

GENERAL FUND.

Receipts.

Cash Balance, March 25, 1899.....		\$224 55
Received from dues.....	\$1060 20	
" " sale of publications.....	44 00	
" " " stationery.....	2 40	
" " advertisements.....	35 00	
" " Security Savings Bank (interest).....	28	
" " Life Membership Fund (interest).....	76 74	
" " Bruce Medal Fund, advance of Feb. 27, 1899, returned...	59 97	
	<u>\$1278 59</u>	
Less transfer to Life Membership Fund.....	50 00	1228 59
		<u>\$1453 14</u>

Expenditures.

For publications: printing.....	\$739 70	
" " : illustrations (cuts).....	26 36	
	<u>\$766 06</u>	
Stationery and printing	59 15	
Postages.....	77 22	
Rent	180 00	
Salary Secretary-Treasurer.....	180 00	
Expressages.....	5 10	
Janitor and elevator.....	6 50	
Gas.....	1 30	
Taxes	2 45	
Insurance premiums	22 50	
Telegrams.....	2 90	
Collecting dues.....	10 50	
Lantern at lecture, and lecturer's expenses.....	17 75	
Engrossing diplomas.....	2 40	
Engraving two comet medals (Nos. 36 and 37) ..	2 00	
Typewriting and exchange	60	
	<u>\$1336 43</u>	
		\$116 71
Mar. 8, 1900. Advanced to Bruce Medal Fund (third award)...		<u>81 62</u>
Cash Balance, March 31, 1900.....		<u>\$35 09</u>

LIFE MEMBERSHIP FUND.

Cash Balance, March 25, 1899.....	\$2053 95
Received from General Fund.....	50 00
" " Interest for 1899.....	76 74
	<u>\$2180 69</u>
Less interest transferred to General Fund	76 74
Cash Balance, March 31, 1900.....	<u>\$2103 95</u>

DONOHUE COMET-MEDAL FUND.

Cash Balance, March 25, 1899.....	\$641 72
Interest for 1899.....	23 97
Cash Balance, March 31, 1900.....	<u>\$665 69</u>

Publications of the

BRUCE MEDAL FUND.

Cash Balance, March 25, 1899.		\$2500 00
Interest for 1899.		80 30
March 8, 1900. Cash advanced by General Fund for Third Award.		81 62
		<u>\$2661 92</u>
Oct. 4, 1899. Cash of Feb. 27, 1899, returned to General Fund.	\$59 97	
March 9, 1900. Remittance to A. DuBois for one Gold Medal (Third Award).	101 95	161 92
Cash Balance, March 31, 1900		<u>\$2500 00</u>

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance, March 25, 1899.		\$1517 90
Interest for 1899.		56 16
		<u>\$1574 06</u>
Less expenditures: Vol. 1, Astronomical Journal.	\$9 00	
Subscription, Popular Astronomy.	2 50	
Librarian.	1 75	
Hicks-Judd Co., for binding.	37 70	50 95
		<u>\$1523 11</u>

FUNDS.

Balances on Deposit as follows:

General Fund:		
with Donohoe Kelly Banking Co.	\$25 33	
" Security Savings Bank.	9 76	\$35 09
Life Membership Fund:		
with San Francisco Savings Union.	\$903 95	
" German Savings and Loan Society.	600 00	
" Hibernia Savings and Loan Society.	600 00	\$2103 95
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union.	\$221 95	
" German Savings and Loan Society.	216 43	
" Hibernia Savings and Loan Society.	227 31	\$665 69
Alexander Montgomery Library Fund:		
with San Francisco Savings Union.	\$502 87	
" German Savings and Loan Society.	416 06	
" Hibernia Savings and Loan Society.	604 18	\$1523 11
Bruce Medal Fund:		
with San Francisco Savings Union.	\$1250 00	
" Security Savings Bank.	625 00	
" German Savings and Loan Society.	625 00	\$2500 00
		<u>\$5827 84</u>

SAN FRANCISCO, March 31, 1900.

F. R. ZIEL, *Treasurer.*

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN—Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 31, 1900, have made a careful examination, and find same to be correct.

Yours respectfully,

O. VON GELDERN,
F. H. McCONNELL.

March 31, 1900.

The following resolution was, upon motion by Mr. PIERSON, adopted :—

Resolved, That in the death of Miss CATHERINE WOLFE BRUCE, which has just been announced to this Society, science has suffered an irreparable loss, and this Society a sympathizing and generous friend. Although suffering for years from a painful illness, she yet rarely refused to stretch forth a bounteous hand in aid of astronomical science. To recount her gifts were needless, for they are part of the annals of the scientific world. Her munificent endowment of the Gold Medal Fund of this Society will stand as a perpetual memorial of her love for astronomy, and the bestowal of the medals she provided, a constantly recurring remembrance both to us and to the recipients of them, of her gracious efforts in aid of the cultivation and diffusion of scientific truth.

The Secretary was directed to forward to Miss M. W. BRUCE a copy of these resolutions.

Mr. CUSHING then read President PARDEE's annual address.

The following resolution was, on motion, adopted :—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 31, 1900, AT 9:30 P. M.

The new Board of Directors was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected :—

President : Mr. JAMES E. KEELER.

First Vice-President : Mr. CHAS. BURCKHALTER.

Second Vice-President : Miss R. O'HALLORAN.

Third Vice-President : Mr. S. D. TOWNLEY.

Secretaries : Messrs. C. D. PERRINE and F. R. ZIEL.

Treasurer : Mr. F. R. ZIEL.

Committee on the Comet-Medal : Messrs. KEELER (*ex-officio*), PIERSON, and BURCKHALTER.

Library Committee : Mr. TOWNLEY, Miss O'HALLORAN, Miss HOBE. Mr. TOWNLEY was appointed Librarian.

Finance Committee : Messrs. PIERSON, BURCKHALTER, HILL.

The Committee on Publication is composed of: Messrs. R. G. AITKEN, S. D. TOWNLEY, O. VON GELDERN.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. JAMES E. KEELER	President
Mr. CHARLES BURCKHALTER	First Vice-President
Miss R. O'HALLORAN,	Second Vice-President
Mr. S. D. TOWNLEY	Third Vice-President
Mr. C. D. PERRINE }	Secretaries
Mr. F. R. ZIEL }	
Mr. F. R. ZIEL	Treasurer
Board of Directors—Messrs. BURCKHALTER, CAMPBELL, DOLBEER, HILL, KEELER, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, TOWNLEY, ZIEL.	
Finance Committee—Messrs. PIERSON, BURCKHALTER, HILL.	
Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.	
Library Committee—Messrs. TOWNLEY, Miss O'HALLORAN, Miss HOBE.	
Committee on the Comet-Medal—Messrs. KEELER (<i>ex-officio</i>), PIERSON, BURCKHALTER.	

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX AND
TILDEN FOUNDATIONS.



THE TRIFID NEBULA IN SAGITTARIUS.
*Photographed with the Crossley Reflector
of the Lick Observatory.*

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1900.

No. 74.

PHOTOGRAPH OF THE TRIFID NEBULA, IN
SAGITTARIUS.

BY JAMES E. KEELER.

The "Trifid" Nebula, *Messier 20*, in *Sagittarius*, is one of the most beautiful and remarkable of the irregular nebulae. Its name is derived from the appearance which it presents in visual telescopes, and more particularly from the description of Sir JOHN HERSCHEL:—

"One of them [several nebulae in *Sagittarius*] is singularly trifid, consisting of three bright and irregularly formed nebulous masses, graduating away insensibly externally, but coming up to a great intensity of light at their interior edges, where they inclose and surround a sort of three-forked rift, or vacant area, abruptly and uncouthly crooked, and quite void of nebulous light. A beautiful triple star is situated precisely on the edge of one of these nebulous masses just where the interior vacancy forks out into two channels. A fourth nebulous mass spreads like a fan or downy plume from a star at a little distance from the triple nebula."^{*}

Numerous drawings of the Trifid Nebula have been published. Two by LASSELL in the *Memoirs of the Royal Astronomical Society* represent the brightest parts of nebula very well. There is a good drawing by TROUVELOT, showing the whole nebula, among the astronomical drawings in volume VIII of the *Annals of the Harvard College Observatory*. It has been copied into a number of popular books on astronomy.

The photographure of the Trifid Nebula which accompanies the present article was made from a photograph taken with the Crossley reflector on the night of July 6, 1899. The exposure given to the original negative was three hours. The enlarge-

^{*} "Outline of Astronomy," p. 611.



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*Photographed with the Crossley Reflector
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*"Outlines of Astronomy," p. 611.

ment of the photogravure, as compared with the negative, is 2.9 diameters, and $1^{\text{mm}} = 13$ seconds of arc.

The photograph agrees well with the drawings, but it shows very much more than they do. The three main rifts referred to in Sir JOHN HERSCHEL'S description are seen, ramifying in all directions, like the roots of a tree, and may be traced nearly to the limits of the plate. Besides these rifts, there are many others, extending through the fainter part of the nebula, which in TROUVELOT'S drawing is represented by a uniform patch of nebulosity.

The triple star, referred to by HERSCHEL, and shown in the different drawings which have been mentioned, is, on the photograph, lost in the bright patch of nebulosity bordering on two of the main rifts. It is visible on the negative, but could not be brought out on the enlargement.

According to Dr. HOLDEN, the observations and drawings of this nebula afford strong evidence that there has been a change in the relative position of the nebula and some of the involved stars. A drawing by HERSCHEL in the *Philosophical Transactions* (1833) shows the triple star in the middle of the dark space formed by the three principal lanes, and in several early observations the star is stated to have this position. Later observations and drawings place the star just within the outline of the nebula. But Dr. DREYER has pointed out that the drawing of 1833 was constructed from sketches "the rudest imaginable, aided by memory," while the observations were made under unfavorable circumstances. A drawing made by Sir JOHN HERSCHEL in 1835 shows the star in its present position. The change, if there was one, must have occurred suddenly, which is not, in general, the nature of cosmical changes. Since 1835 there has been no change in the relative positions of the star and the nebula. In all probability, therefore, the inferred proper motion of the nebula is illusory.

It is certain that the more frequently one has to compare drawings and photographs of nebulæ, the less one is inclined to attach weight to evidence based on the drawings.

NOTES ON THE PROGRESS OF DOUBLE-STAR
ASTRONOMY.*

BY WILLIAM J. HUSSEY.

It is nearly a hundred years since Sir WILLIAM HERSCHEL, as a result of the comparison of measures which he had just obtained with others made by him some twenty years earlier, was able to announce half a dozen cases in which he had found one star revolving about another. At that time this was a wonderful discovery. Astronomers had not expected to find suns moving in this manner, and it is not surprising that they were amazed when HERSCHEL proved this to be the case by producing such an array of facts and arguments that no room was left to doubt the correctness of his conclusions.

Previously but little attention had been given to the stars for their own sakes. With instruments such as were in use, perhaps it was thought that not much of interest could be ascertained concerning them. As reference-points in the sky they had been of use (and are so still) in facilitating the investigations of the motions of the bodies composing the solar system, and it does not appear to have been imagined that there is great variety among them. HERSCHEL's discovery was one of the factors which have operated to change all this. He showed that the stars are not all after the same pattern, but that they have their several stories to tell to those who will interrogate them properly, and ever since his time astronomers have more and more been finding this to be the case. New departments of sidereal investigation have come into existence. Besides all that relates to the absolute positions and movements of the stars as determined by the meridian observations, and those relative changes which are ascertained from the micrometrical measures, there are the extensive fields of research in which are considered those strange variations of light exhibited by certain of the stars, and the multiplied diversity of phenomena which have been revealed by the study of stellar spectra. With larger telescopes, more efficient subsidiary apparatus, more exact theories of instruments and

* This article does not pretend to cover the entire field of double-star astronomy. It gives no account of the numerous determinations of orbits which have appeared from time to time, and nothing concerning spectroscopic binaries of which quite a number have recently been discovered.

methods, and a greater number of enthusiastic investigators, results of greater variety and ever-increasing interest and importance are being obtained. In this rapid movement forward which now characterizes sidereal astronomy, that part which relates to double stars, visually considered, follows methods which have been in use for many years, and it appears probable that this will continue to be the case for all of the more interesting systems.

The number of stars which have been catalogued as double and multiple has reached the formidable aggregate of over thirteen thousand. The majority of these are the discoveries of long ago. The catalogues of the HERSCHELS and the STRUVES alone contain more than nine thousand entries. But many of these are wide and easy pairs, whose components sustain no known physical relation to each other, and which are of such a character that were they now found for the first time no one would think of cataloguing them as double stars.

For nearly forty years, dating from 1782, Sir WILLIAM HERSCHEL was almost the only observer of double stars. Eight hundred and twelve of those which he observed have been identified. Many of these were his own discoveries, and all of the more important ones were included by STRUVE in the Dorpat Catalogue.

Sir JOHN HERSCHEL began his long career in astronomy in 1816 by taking up, under his father's direction, the re-examination of all the double stars discovered by him. By a fortunate circumstance, he worked from 1821 to 1823 in conjunction with Sir JAMES SOUTH, at the latter's private observatory in London. This was provided with two telescopes of very modest dimensions according to our present standards. One was three and three-quarters and the other five inches aperture. With these little instruments, not supplied with driving-clocks, these observers made a series of observations of 380 double stars, which is remarkable for the skill, patience, and accuracy with which it was executed, and for the confirmation of the phenomena first brought to light by Sir WILLIAM HERSCHEL.

These observations of SOUTH and HERSCHEL were published in the *Philosophical Transactions* for 1824, and won for them the Lalande Prize of the French Academy in 1825, and gold medals from the Royal Astronomical Society in the following year. At the same time this society presented its gold medal to WILLIAM

STRUVE for the double-star observations which he had made at Dorpat, and made honorable mention of the work of AMICI at Modena in the same direction. These four were the only double-star observers then living.

Previous to this time STRUVE had been using a very modest telescope in his double-star work. But in 1824 FRAUNHOFER completed for the Dorpat Observatory the celebrated refractor of nearly nine and a half inches aperture. This was equatorially mounted, and provided with a good driving-clock. For fifteen years it remained the largest refractor in the world, and during that time it was by far the most efficient telescope in existence for double-star work.

On receiving this equatorial, STRUVE resolved to reobserve all the double stars then known from the north pole to 15° South Declination, and to examine carefully all the brighter stars within this region for the purpose of discovering new pairs. In the course of this survey he is said to have examined no fewer than 120,000 stars. As a result of the first two years' work upon this programme, he published in 1827 the Dorpat Catalogue of 3,065 double and multiple stars. In this were included not only his own discoveries, but also all other objects which had been found by other astronomers within 105° of the north pole, and which appeared to him worthy of being called double stars.

The second part of STRUVE's programme was more arduous and required a greater time. To obtain exact micrometrical observations of all the double stars of the Dorpat Catalogue which are worthy of attention is no small undertaking, and it is surprising that STRUVE accomplished it in the comparatively short interval of twelve years. In 1837 he published the "*Mensuræ Micrometricæ*," a ponderous folio, containing the observations made at Dorpat with the large equatorial from 1824 to 1836, together with the results which he had obtained with a smaller instrument from 1813 to 1824. It also contained many of the observations by the HERSCHELS and SOUTH, so that it may be said that this volume gave all that was known at the time of its publication concerning the double stars of the Dorpat Catalogue. When the objects of this catalogue came to be critically examined, it was found that some had distances greater than $32''$, which was the maximum limit set by STRUVE; that some were not double; that some were identical with others, erroneous positions having been assigned to them. For these and various

other reasons 492 were rejected, or about sixteen per cent. of the entire number.

About 1827, Sir JOHN HERSCHEL began a series of "sweeps" with large reflecting telescopes, which resulted in the discovery of large numbers of nebulae and 5,533 double and multiple stars. Some of these are in the northern and some in the southern hemisphere. Many of these double stars have little claim to be called such, consisting, as they frequently do, of wide pairs of faint stars. Many of them have not been measured since their discovery, and even at that time the angles alone were measured, the distances were estimated. Taken as a whole, they are of little consequence, except that they swell enormously the number of objects listed as double stars.

In 1839 the great Russian Observatory at Pulkowa was established, and WILLIAM STRUVE was called from Dorpat to be its first Director. Its largest instrument was the 15-inch refractor. With this, in 1841 and 1842, OTTO STRUVE examined all the brighter stars north of the equator, and by doing so discovered a large number of close and difficult double stars. His first catalogue contains 514 objects, which subsequent discoveries increased to 547. In this catalogue it was intended that the distances should all be less than 32", and the magnitude of the principal star, or the combined magnitude of the two in the case of close doubles, not to descend below 7.8. As companions all stars at distances less than 16" and bright enough to be readily measurable with the 15-inch telescope were admitted, while for distances between 16" and 32" the limiting inferior magnitude was 8.9. When the stars came to be measured, it was found that some fell outside of the limits just described, and for this and other reasons 106 of the objects enumerated in the first edition of the Pulkowa Catalogue were rejected.

Sir WILLIAM HERSCHEL's work on double stars had begun in his attempt to find suitable pairs of stars for the determination of stellar parallaxes. Having satisfied himself that in these investigations the method of double stars would have many advantages over any other, he states that he resolved to examine every star in the heavens with the utmost attention and with a very high power, in order to ascertain what stars are best suited to this research, so that he might make his observations on those that promised the best results.

We have noted that WILLIAM STRUVE examined no less than

120,000 stars within 105° of the north celestial pole with the Dorpat refractor, for the express purpose of discovering those which are double. Sir JOHN HERSCHEL swept both the northern and the southern heavens in quest of double stars and nebulae. Finally OTTO STRUVE made the Pulkowa refractor famous by reason of the large number of difficult double stars which he discovered with it, in the course of his examination of all the brighter stars in the northern sky. After all of these examinations by experienced observers armed with powerful telescopes, it is no wonder that the astronomers at the middle of the nineteenth century were disposed to think that all or nearly all of the interesting double stars had already been discovered, and that what remained to be accomplished in this field was to continue the observation of those already known and to compute the orbits of the binaries whenever the data for the purpose became sufficient. For thirty years following the publication of the Pulkowa Catalogue very few double stars were discovered. During this time, however, some remarkable series of observations were obtained. To this period belong the observations by OTTO STRUVE, MADLER, DAWES, SECCHI, and DEMBOWSKI, not to mention others. Their observations have served to determine the character of the motion, where any is shown, in the great majority of the stars contained in the Dorpat and Pulkowa catalogues; and if the information which is now scattered through many publications were brought together and printed in convenient form, the astronomers of the future would have but little difficulty in ascertaining what further attention, if any, is desirable in the case of any of the double stars contained in these extensive catalogues. Such publication of the data now available would most effectively advance the interests of this department of astronomy, by practically removing from consideration the large numbers of these stars which have shown little or no motion, and explicitly pointing out those which are in need of further attention.

The revival of the discovery of double stars dates from 1873, when BURNHAM began to publish accounts of those which he found with his 6-inch telescope at Chicago. In this year he published three catalogues in the *Monthly Notices* of the Royal Astronomical Society, announcing 182 new double stars. Since that time discovery has proceeded rapidly, as is shown by the following summary, which gives approximately the numbers of

NEW DOUBLE STARS DISCOVERED BY VARIOUS
OBSERVERS SINCE 1870.

BURNHAM.....	1,290
HOUGH	623
SEE	500
INNES.....	305
Cincinnati Observatory observers.....	181
Washburn Observatory observers.....	171
Harvard and Arequipa observers.....	109
HUSSEY	100
AITKEN	47
Miscellaneous, perhaps about.....	200
	3 526

This list does not profess to be complete. It is merely intended to indicate the large number of discoveries which have been made during the past thirty years. It is well known that several observers have recently found considerable numbers of new double stars which are still unannounced.

The double stars of the lists above include a great majority of the closest and most difficult pairs known, and a large number of rapid and interesting binaries. Professor BURNHAM's discoveries alone include 690 pairs having distances not exceeding 2'', while there are only 680 such pairs among the more than nine thousand double stars that had been catalogued before 1870. The discovery of so many close and difficult stars has added enormously to the labor in this department of astronomy, but this has its compensation in the rapid increase in the number of known physical pairs, and in the important additions to our knowledge respecting them.

These circumstances have given the subject a greater interest. The number of observers has increased somewhat, but hardly in proportion to the increased number of instruments available for such work, and the literature has become much more extensive and scattered than formerly. This state of affairs has both advantages and disadvantages. A greater number of observers insures more measures, a less likelihood that important pairs will long be overlooked, and more complete data for the determinations of orbits, and of systematic and accidental errors of observation. But, on the other hand, the observations are being scattered through a great variety of publications, and it has become an exceedingly difficult matter for the average observer to ascertain what stars have already received sufficient attention and what

ones should be kept on the observing list. In most cases it is far easier to make a new set of observations of a given star than to examine the literature thoroughly to see whether such observations are needed. Any additions, therefore, to the works which collect and classify the material already available in this department of astronomy makes for progress, and it is a pleasure to note that two such books, both of great importance, have recently appeared. The first volume of the Publications of the Yerkes Observatory is "A GENERAL CATALOGUE OF 1,290 DOUBLE STARS DISCOVERED FROM 1871 TO 1899 BY S. W. BURNHAM," and Part II of Volume II of the Annals of the Royal Observatory, Cape of Good Hope, is a "REFERENCE CATALOGUE OF SOUTHERN DOUBLE STARS, BY R. T. A. INNES."

Professor BURNHAM has given an excellent statement of the needs which led to the preparation of his General Catalogue in the opening words of his introduction, as follows:—

"A general catalogue of all the double stars discovered by me from time to time during the past twenty-five years has long been needed by those interested in this field of astronomical research, and, by reason of the special interest attached to many of these remote sidereal systems, it has become more and more important to bring the scattered material together in order to intelligently pursue the investigations which promise to so much increase our knowledge of the great universe beyond the solar system. These discoveries are scattered through nineteen different catalogues, published at various times and places, commencing with 1873; and the observation of these stars by a great number of astronomers in this country and in Europe can only be made use of by consulting hundreds of volumes of observatory and society publications, astronomical periodicals, etc. It is difficult, if not practically impossible, for the general observer or investigator to make a really complete collection of all the measures of a large number of these stars. Many of the observations are in obscure and unusual places, and in works not always readily accessible."

Professor BURNHAM's General Catalogue covers its ground very completely; and not only in the arrangement of its material, but also in its typographical effect, it is a model of excellence which may well be followed in other books of a similar character. It gives a record of all the double stars discovered by BURNHAM through a long series of years. Nothing essential to their histories is wanting, and nothing superfluous added. The stars are arranged in the order of Right Ascension. The mean results of all the observations of each pair are given in chronological order. These are followed by notes of such length as may be needed to

give an account of the discovery, the character of the pair, the circumstances of its motion, and any other facts of interest or importance concerning it. Diagrams are freely used to illustrate the motions of the more interesting cases. Finally, each pair is accompanied by references to all the original sources of information.

It is not likely that the importance of this work will be overestimated. Having it at hand, it will generally be possible to see at a glance, from the data which it contains, whether the components of any given pair are in motion or not, and thus the future observer may readily select from among these stars those which are needing observation and which are likely to lead to interesting results. Moreover, this selection will be the more easy, for Professor BURNHAM has given a provisional list of 185 pairs which have already furnished more or less evidence of being physical systems. Some of these are rapidly moving binaries. The orbits of eight have already been computed. These include κ *Pegasi* whose period (11.42 years) is the shortest known among the visual binaries.

In the introduction to his volume Professor BURNHAM has given a brief history of the beginning of his astronomical career. Since this is of very general interest, I quote a portion of it, as follows:—

“When in London, about 1861, I purchased one of the cheap astronomical telescopes introduced about that time. It had a nominal aperture of three inches, but was without a finder, and had only the simple altazimuth mounting, with a common table tripod. It was supplied with a terrestrial as well as astronomical eye-piece, and while it was a good instrument for landscape use, it was of little value for astronomical purposes. Some years later I obtained a $3\frac{1}{4}$ -inch telescope, with an English object-glass, mounted equatorially by FITZ on a portable stand. This was just good enough to be of some use, and poor enough, so far as its optical power was concerned, to make something better more desirable than ever. In 1869 I accidentally met Mr. ALVAN G. CLARK in Chicago on his return from Iowa, where he had been to observe the total eclipse of that year, and made some inquiries of him concerning a small equatorial. The interview resulted in my ordering from the celebrated firm of ALVAN CLARK & SONS an equatorial of six inches aperture. I told them what I wanted and what I wanted it for. Every detail was left entirely to their judgment, stipulating only that its definition should be as perfect as they could make it, and that it should do on double stars all that it was possible for any instrument of that aperture to do. In due course of time this instrument was delivered, and was set up in an observatory prepared for it in the mean time. My attention, for

some reason or other which I am unable to explain had been almost exclusively directed to double stars previous to this while using the smaller telescope referred to. This preference was not in any sense a matter of judgment as to the most desirable or profitable department of astronomical work, or the result of any special deliberation upon the subject. It came about naturally, without any effort or direction upon my part."

By adhering to this one line of astronomical work, becoming familiar with its extensive literature, and by a still more effective examination of the sky, Mr. BURNHAM has attained a more complete mastery of this department of astronomical work than any other man has done. All of the double stars discovered by him have been found with telescopes having objectives by ALVAN CLARK & SONS. Over eight hundred of his discoveries were made in Chicago, and nearly three hundred at the Lick Observatory. Their distribution among the several telescopes, which he used at various times, is given as follows:—

6-inch—Private Observatory	451
18½-inch—Dearborn Observatory	413
36-inch—Lick Observatory	198
15½-inch—Washburn Observatory	87
12-inch—Lick Observatory	56
9.4 inch—Dartmouth College Observatory	24
26-inch—U. S. Naval Observatory	14
40-inch—Yerkes Observatory	8
16-inch—Warner Observatory	2

The gold medal of the Royal Astronomical Society was awarded to Mr. BURNHAM in 1894 for his double-star discoveries and investigations.

Comparatively little has been done upon the double stars of the southern hemisphere, and until the appearance of Mr. INNES'S book no general catalogue of them had been published. Hitherto, observers desiring to work in that field had three courses open to them: they could spend their time in searching for suitable objects in the sky, or they could confine their attention to those in the vicinity of the equator which generally had been discovered by northern astronomers and measured by them, or they could search through many publications to ascertain what southern stars were in need of attention and likely to lead to interesting and valuable results.

Mr. INNES has done much to remove the difficulties which have confronted observers, and his book cannot fail to have a

wide influence in stimulating the study of the double stars situated in a region heretofore considerably neglected. He has given descriptions of about twenty-two hundred double stars belonging to the southern hemisphere. These are arranged in the order of Right Ascension. Each pair is accompanied by a selection of the micrometrical measures which have been made upon it, and from these it is frequently possible to form an idea respecting the state of rest or motion of the components. Notes are sparingly used, and usually relate to questions of motion, magnitudes, etc. Except in a few cases, such as *Sirius* and *α Centauri*, references to original sources of information are not given in connection with each pair, but at the end of the volume we find an extensive list of books and papers "chiefly limited to treatises of general interest or such as contain observations of southern double stars."

Mr. INNES has deemed it impracticable to include in his catalogue all the objects of the southern hemisphere which at one time or another have found their way into the lists of double stars. In order to have a criterion for the rejection of undesirable pairs, he has adopted the scale of limiting distances according to magnitude given in the following table:—

Magnitude of Primary.	Limiting Distance of Components.
1	30"
2	25
3	20
4	15
5	10
6	7
7	5
8	3
9	1

In the beginning it would no doubt have been better if the limits as to distance had been more restricted, and if large numbers of wide pairs had never been catalogued. But it is difficult effectively to remove a star which has appeared in the lists; and however much we may regard the action of Mr. INNES in restricting the distances to narrow limits as a move in the right direction, we still have a lingering wish that he might have

included all known pairs in his book. At times he has found it necessary to set aside the limits which he has adopted. This has been done in order to retain "many wide pairs, worthy of inclusion from some point of view." Among these are "some systems much exceeding the above distances and showing no certain signs of orbital motion," but which have been retained "on account of large proper motion common to both components." But perhaps the most serious objection to the general adoption of the above scale of distances is, that the limits for the fainter magnitudes are so narrow that some of the northern binaries would be excluded, and it is not impossible that this may also be the case with some of those of the southern hemisphere. The companion to μ *Herculis* is an example. The magnitudes of the components of this pair are 9.4, and 10, and the period in which they complete a revolution is about forty-five years. According to my measures with the thirty-six-inch refractor, the distance last year was 1".54. The last star in the Pulkowa Catalogue, O Σ 547, is another example. The magnitudes in this case are 8.3 and 8.3, and in 1898, the distance which I obtained as a result of three nights' measures was 4".62. Not only do these stars have a common proper motion of nearly a second a year, but from the time of the first micrometrical observations the position-angle has been increasing about three fourths of a degree per year without appreciable change of distance.

In the various double-star catalogues are to be found many pairs consisting of a bright star and a distant faint companion. The distance between the components of many of these pairs is so great that they would now probably be considered unworthy of attention by any one looking for new double stars. In some cases these pairs have exhibited changes in position-angle and distance, which may be traced to the difference of the proper motions of the two stars, but the majority have shown no certain change in the relative positions of their components during the period over which the micrometrical observations extend. Nevertheless, among these pairs are many examples in which the proper motion of the principal star has been determined from meridian observations, and found to be so large that a marked change in position-angle and distance would take place in a comparatively short time, were it not that the companion has the same proper motion as the principal star. These cases are so

numerous that they cannot be ascribed to fortuitous circumstances, and we are compelled to admit that the stars which are moving together in this manner are physically related. How wide may be the limits over which this physical connection extends no one at present can tell. The photographs of large nebulae frequently exhibit arrangements of stars which so closely conform to the nebular outlines as to afford some evidence that the stars and nebula are physically associated. A nebula may cover a large area, but however extensive it may be, we entertain no doubt as to the physical connection of its various parts. With some reason, then, we may also assume a possible physical relationship of the stars which appear to be associated with it. If this be granted, we have at once a far wider limit of apparent distance than has been admitted in any of the extensive catalogues of double stars.

The considerations just given do not afford an argument of any particular force in favor of including additional wide pairs in future catalogues of double stars. It may be well to retain those which have been micrometrically measured at various epochs, and to obtain occasional additional observations of them in the future; for it may be that these measures will eventually furnish some valuable information concerning the motions which are slowly taking place among these distant sidereal systems.

But there appears to be no sufficient reason for adding to their number, as would be an easy matter with the large telescopes of the present time. On the contrary, in the case of new discoveries, there is a decided tendency to adopt limits only a little wider than is necessary to include the known binaries, to the end that the number of objects to be considered may not become unmanageably large, and that the lists may have an average higher interest. Besides, there is another consideration. Large distances can be obtained more accurately from the measurement of large-scale photographs than directly with the micrometer. On this account it is not inappropriate to leave the wide and easy pairs for photographic measurement.

The attempts which have been made to obtain the position-angles and distances of moderately close and unequal pairs through the medium of photography cannot be said to have been attended with much success, either when we consider the number of measures obtained or the character of the pairs. The photographic method has its limitations. These are such as render it worthless in investigations relating to the closest and most diffi-

cult double stars, which are the ones that include all of the rapid binaries. In this field of work the visual and the photographic methods are not competitors. The reason is simple enough. The eye can see as double what the photographic plate, used in an instrument of practicable dimensions, would certainly record as single. The images of the components of a close double star as formed by the objective of the telescope are very near each other. Thus, the scale for the 12-inch telescope of the Lick Observatory is $1/1100$ th of an inch to 1", and that for the 36-inch refractor $1/297$ th of an inch to 1". Under the most favorable circumstances the eye is able to detect the elongation produced by the partial overlapping of equal stellar images when their centers are not more than $1/5000$ th of an inch apart. The photographic plate does not possess resolving power to this extent. The silver grains in the film have dimensions probably twice as large. Besides, for objects such as double stars, photographic images not larger than the silver grains cannot be realized. The light spreads through the film, the area over which the photographic action extends becomes enlarged, the image of a bright star obliterates that of its faint companion, and in the case of close and equal pairs the images of the two components are merged together and lose their identity.

MT. HAMILTON, CALIFORNIA, May 29, 1900.

THE ORBIT OF *T CYGNI*. (A. G. C. 13.)

By R. G. AITKEN.

The companion to *T Cygni* was discovered by ALVAN G. CLARK in October, 1874, with the 26-inch telescope now mounted at the Leander McCormick Observatory. The first measures were secured in the same year by NEWCOMB, with the 26-inch refractor of the Naval Observatory, and by DEMBOWSKI, with an instrument of only seven inches aperture. The latter observer demonstrated the existence of relative motion in this system by his measures during the few years following discovery, and it soon became apparent that this motion was orbital. Other observers also gave the pair attention until 1880; but from that year until 1889,

when BURNHAM began his work with the 36-inch refractor, it was almost wholly neglected. The only observation in this interval (during which the small star described an arc of nearly 100°) that can be used in determining the orbit is one by HALL, on a single night in 1885, to which he appends the note, "Images blazing." Since BURNHAM's measures in 1889, the star has received sufficient attention, but the measures are not as accordant as is desirable.

An orbit for *T Cygni* was computed by GORE (*A. N.*, 2749) in 1886, using the measures to 1885. The arc, however, was so small that the resulting elements were very uncertain. He found a period of 53.87 years. In 1892, BURNHAM attempted to define the orbit using all the measures to date, including his own in 1892.41. His conclusion was that even then, when the arc described by the companion-star was nearly 180° , the discordance of the early and late measures was so great as to make it impossible to determine where the truth lay. He drew an apparent ellipse, however, which would satisfy the observations very well, provided the CLARK companion were assumed to be attended by a "dark" sun of equal mass revolving with it about a common center of gravity in a hypothetical orbit. The ellipse also satisfied the motion of the visible companion without this assumption as well as any that could be drawn at that time. The elements resulting from it are:—

$$\begin{array}{ll} P = 36.5 \text{ years.} & \\ T = 1893.1 & i = 46^\circ.7 \\ e = 0.24 & \Omega = 163.6 \\ a = 0''.94 & \lambda = 164.9 \end{array}$$

Since 1892 the motion of the small star has carried it through an additional arc of more than 50° , giving a total arc of nearly 225° since the first measures. I have therefore thought it possible at this time to make an investigation which shall give results at least approximately correct.

The following are all the published measures of this pair that I have been able to find. Except in the grouping of the first five observations by DEMBOWSKI, the measures to 1892.40, inclusive, are taken as given by BURNHAM in the paper cited.

DATE.	θ	ρ	n	OBSERVER.	O - C.	
					$\Delta \theta$	$\Delta \rho$
1874.89	162.6	1.11	2	NEWCOMB	- 0.6	-0.02
74.90	174.8	1.06	1	DEMBOWSKI...	+11.6	-0.07
75.60	171.4	1.35	4	"	+11.3	+0.23
76.79	161.5	1.25	2	"	+ 5.2	+0.15
76.83	166.9	1.62	2	WALDO.....	+10.7	+0.53
76.90	160.2	1.04	2	HALL.....	+ 4.3	-0.05
77.70	155.3	1.25	8	DEMBOWSKI...	+ 2.4	+0.17
78.41	150.0	1.06	1	BURNHAM ...	0.0	+0.01
78.54	147.5	1.09	3	DEMBOWSKI...	- 2.0	+0.05
78.76	158.8	1.09	2, 1	HALL	+10.2	+0.05
79.50	148.3	0.90	2	BURNHAM.....	+ 2.9	-0.10
79.75	147.3	0.98	6, 5	HALL.....	+ 3.1	-0.01
80.77	137.4	1.04	1	FRISBY.....	+ 1.8	+0.10
83.88	159.2		3	SEABROKE	-41.0	
85.52	116.3	1.08	3	TARRANT.....	+15.2	+0.48
85.74	100.7	0.62	1	HALL	+ 2.4	+0.03
86.78	80 $\pm$	0.5 $\pm$	1	HOUGH.....	- 3 $\pm$	0.0 $\pm$
87.76	56.4	0.4 $\pm$	1	"	-10.3	-0.1 $\pm$
89.49	36.5	0.50	4	BURNHAM.....	- 1.1	-0.04
90.54	20.5	0.54	3	"	- 1.9	-0.05
91.49	12.4	0.61	3	"	+ 1.3	-0.04
91.70	9.3	0.52	3	HALL.....	+ 0.7	-0.13
92.41	2.3	0.61	3	BURNHAM.....	+ 0.6	-0.08
92.72	358.4	0.60	3	COMSTOCK	- 0.3	-0.11
94.77	344.4	0.78	5	BARNARD.....	+ 1.9	-0.01
95.71	335.1	0.86	2	COMSTOCK.....	- 0.8	+0.06
95.73	332.6	0.29 $\pm$	3	SEE	- 3.2	-0.51 $\pm$
96.55	333.6	0.79	3	AITKEN.....	+ 3.4	-0.02
96.64	340.9	0.48	2, 1	LEWIS.....	+11.4	-0.33
96.67	330.9	0.69	3	COMSTOCK	+ 1.6	-0.12
96.82	332.1	0.73	6	HUSSEY.....	+ 3.8	-0.08
97.57	322.4	0.68	3	AITKEN.....	- 0.7	-0.12
97.72	326.4	0.94	3	DOBERCK.....	+ 4.4	+0.14
97.81	328.5	0.72	5	HUSSEY.....	+ 7.1	-0.08
98.49	316.6	0.77	4	AITKEN.....	+ 0.2	-0.01
98.82	311.2	0.58	1	LEWIS.....	- 2.7	-0.20
99.73	308.8	0.80	6	AITKEN.....	+ 2.0	+0.06
99.86	310.0	0.85	3	HUSSEY.....	+ 4.2	+0.11

In forming annual means from these observations, the incomplete measures were disregarded; also the results obtained by WALDO, by TARRANT, and by LEWIS in 1896. The arithmetical mean of the measures in each year was then taken, all the

observations being regarded as of equal weight. The resulting positions are:—

DATE.	θ	ρ	n	OBSERVER.	O - C.	
					$\Delta \theta$	$\Delta \rho$
1874.90	166°.7	1.09	3	N- Δ	+3.5	-0.04
1875.60	171.4	1.35	4	Δ	+11.3	+0.23
1876.85	160.8	1.14	4	Δ -Hl.....	+4.8	+0.05
1877.70	155.3	1.25	8	Δ	+2.4	+0.17
1878.59	151.7	1.08	6, 5	Δ -Hl- β	+2.4	+0.04
1879.69	147.6	0.96	8, 7	β -Hl.....	+3.0	-0.03
1880.77	137.4	1.04	1	F.....	-1.8	+0.10
1885.79	100.7	0.62	1	Hl.....	+2.4	+0.03
1889.49	36.5	0.50	4	β	-1.1	-0.04
1890.54	20.5	0.54	3	β	-1.9	-0.05
1891.60	10.8	0.56	6	β -Hl.....	+1.0	-0.04
1892.56	0.4	0.61	6	β -C.....	0.0	-0.10
1894.77	344.4	0.78	5	Bar.....	+1.9	-0.01
1895.71	335.1	0.86	2	C.....	-0.8	+0.06
1896.72	332.2	0.73	12	C-Hy-A....	+3.2	-0.08
1897.72	326.3	0.77	11	Hy-Dob-A. .	+4.2	-0.03
1898.56	315.5	0.73	5	L-A.....	-0.4	-0.05
1899.77	309.2	0.82	9	Hy-A.....	+2.7	+0.08

It is apparent that no ellipse can be drawn that will represent all of these positions with satisfactory accuracy. To satisfy the law of areas even approximately, some of the distance measures must be considered to be in error. I finally decided to assume that DEMBOWSKI had overmeasured the distance considerably in the years 1875-76-77. That this assumption is allowable, will, I think, be admitted when the size of DEMBOWSKI's telescope is considered in connection with the difference in brightness of the two components of this pair, and the discordance of recent distance measures made with instruments of large aperture. With this assumption, it became possible to draw an ellipse that would represent with reasonable accuracy the majority of the measures.

This ellipse gives by the graphical method, the following set of elements:—

$$P = 45.1 \text{ years.}$$

$$T = 1892.33$$

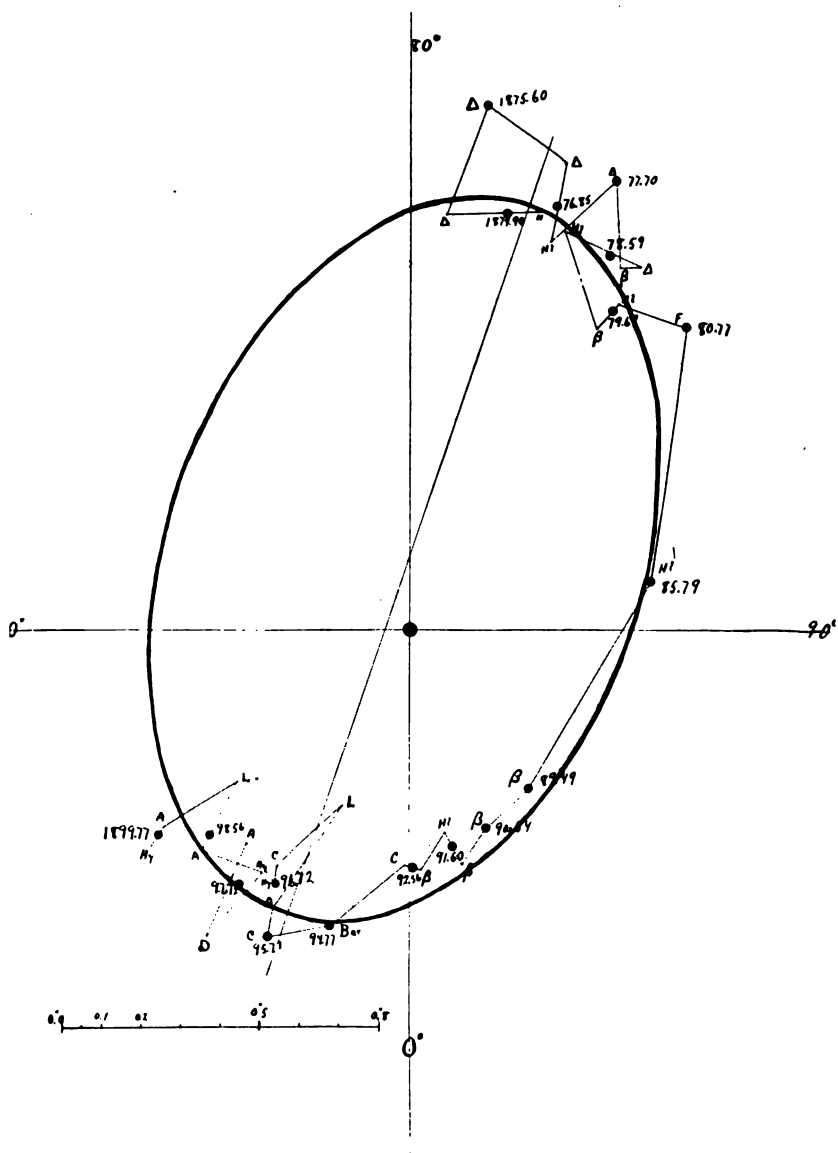
$$e = 0.20$$

$$a = 0''.97$$

$$i = 52^\circ.2$$

$$\Omega = 158.8$$

$$\lambda = 144.5$$



APPARENT ORBIT.

Length of major axis =	1".96
Length of minor axis =	1 .20
Position-angle of major axis =	165°.0
Position-angle of periastron =	2 .4
Distance of star from center =	0 .18

In the diagram accompanying this paper, the small black circles represent the annual means upon which the apparent ellipse is based, and the vertices of the broken line the results obtained by the respective observers. The discordant character of the observations is manifest, as well as the general agreement with the computed positions.

In the two preceding tables the columns following the names of the observers give the residuals in angle and distance.

To test the accuracy of these elements by future observations, I have computed an ephemeris for the next five years:—

Date.	θ	ρ
1900.75	298°.2	0".71
1901.75	288 .9	0 .68
1902.75	278 .8	0 .66
1903.75	268 .1	0 .64
1904.75	257 .1	0 .64

LICK OBSERVATORY, March 23, 1900.

NOTE.—I have just received the *Astronomische Nachrichten*, 3629, which contains Professor T. J. J. SEE's "Researches on the Orbit of *T Cygni*." Professor SEE has in the main used the data given above, though the early observations are combined differently. He has also, apparently, used the results obtained by WALDO and TARRANT; but by some oversight has not used the measures by BARNARD in 1894, HUSSEY in 1896 and 1897, LEWIS in 1896 and 1898, DOBERCK in 1897, and AITKEN in 1897 (twenty-five observations in all). In place of the unpublished Lick Observatory measures in 1899, he has used the unpublished Naval Observatory measures for practically the same epoch.

As Professor SEE's elements differ decidedly from those given above, I copy them here together with his ephemeris, for purposes of comparison. They are:—

$P = 57.25$ years.	
$T = 1890.25$	$i = 55^\circ.6$
$e = 0.370$	$\Omega = 161^\circ.4$
$a = 1''.16$	$\lambda = 121.8$

APPARENT ORBIT.	EPHEMERIS.		
Length of major axis = $2''.18$	1900.70	$307^{\circ}.0$	$0''.84$
Length of minor axis = $1''.25$	1901.70	$301^{\circ}.3$	$0''.82$
Position-angle of major axis = $165^{\circ}.6$	1902.70	$294^{\circ}.9$	$0''.81$
Position-angle of periastron = $24^{\circ}.8$	1903.70	$288^{\circ}.6$	$0''.80$
Distance of star from center = $0''.30$	1904.70	$282^{\circ}.0$	$0''.80$

From a comparison of two sets of ephemerides, it is apparent that the measures of the next two or three years will show which orbit is nearer the truth.

April 5, 1900.

THE DEVELOPMENT OF ASTRONOMY IN AMERICA.

Reprinted from *Nature* (London), April 12, 1900.

Sixty years ago the United States had scarcely a single observatory properly equipped for the pursuit of astronomical studies. To-day that country is possessed of the finest observatories in the world, manned by observers of the greatest skill, who devote themselves untiringly to the advancement of the oldest of the sciences.

The success of the American astronomers during this short period has been remarkable. To them we owe important discoveries and precious records in nearly every branch of theoretical and practical astronomy, and especially of late years in the department of astronomical physics. It is impossible here to recount the whole fruits of their labors, but it is worth while to recall a few of the results which we owe to their industry.

The first striking discovery in America was that of *Hyperion*, the seventh satellite of *Saturn*, by G. P. BOND, in 1848. In the same line of work, HALL was rewarded in 1877 by the discovery of the tiny satellites of *Mars*, and more recently BARNARD astonished the world by his detection of the fifth satellite of *Jupiter*, while PICKERING claims to have established the existence of a ninth satellite of *Saturn*. In planetary studies generally, the Americans have been well to the front, and we have seen the unusual spectacle of a powerful refractor primarily devoted with marked success, by Mr. LOWELL, to the delineation of the surfaces of our nearest planetary neighbors. Numerous measurements of the dimensions of the various members of the solar system have also been made, and the theory of their motions has

been greatly advanced, notably by the well-known investigations of NEWCOMB.

Cometary astronomy has likewise benefited by their zeal, many new discoveries having been made, and the orbits of a large number calculated; in this branch the Americans are now more active than ever, no less than six of the seven new comets discovered in 1898 being to their credit. Important investigations relating to meteorites and the orbits of meteor swarms have also been carried out, and the name of Prof. H. A. NEWTON will always be associated with this department of astronomical research.

Sidereal astronomy has been enriched by numerous star catalogues, and double-star observation has been brought to a high standard of perfection by the assiduous efforts of BURNHAM, HALL, and SEE; while PICKERING'S "Harvard Photometry" has given us an invaluable record of the magnitudes of thousands of the brighter stars. The study of variable stars has also been very productive, our most important catalogue of these objects being due to CHANDLER, while a unique atlas of variable stars is in course of publication by Prof. HAGEN; here, as in many other directions, Prof. PICKERING'S ingenuity has been displayed, and he has shown among other things how variables of short period can be readily detected, and the changes studied, by photographic means.

Our catalogues of nebulae discovered since the time of the HERSCHELS include a large number of entries to the credit of American observers, LEWIS SWIFT having specially distinguished himself in this field of work.

Notable work has also been done in the domain of solar physics. YOUNG'S observations of the chromospheric spectrum have only been surpassed by the most recent eclipse photographs, and Prof. HALE was the first to initiate a regular photographic record of the forms of the chromosphere and prominences. Quite recently, the great telescope of the Yerkes Observatory has been used for a very detailed examination of the spectrum of the chromosphere, and even the most minute structure of the carbon flutings in the green has been successfully observed. To Prof. ROWLAND we owe a great catalogue of close upon twenty thousand of the Fraunhofer lines, the positions of which are stated with a degree of accuracy never before attempted; and physicists and astronomers throughout the world are indebted to

this observer for the magnificent diffraction gratings which his skill has placed at their disposal. By the invention of the bolometer, LANGLEY has opened up a new region of the spectrum, and has made numerous important observations by its aid. At the present time a committee of American astronomers is organizing the work to be undertaken during the total eclipse of the Sun next May, and from a preliminary report which has been issued we gather that they are fully alive to the opportunities which such an event affords.

Astronomy owes an immense debt to photography, and it should not be forgotten that the first photographic impression of a star was obtained on the other side of the Atlantic, by Prof. BOND, in 1850. Among those who early recognized the possibilities of astronomical photography was RUTHERFURD, of New York, who obtained numerous pictures of the Sun, Moon, and stars in the early 'seventies, the full value of which has only lately begun to appear. It was there also that Dr. DRAPER, in 1872, secured the first photograph of a stellar spectrum which revealed anything relating to the composition of a star, and that BARNARD, in 1892, made the first discovery of a comet by the aid of the camera.

The story, however, by no means ends with this pioneer work; celestial photography has been pursued with the greatest success in every direction, notable among the results being BARNARD'S photographic delineation of comets, nebulae, and the Milky Way, and the magnificent spectroscopic work of the Henry Draper Memorial carried on by Prof. PICKERING at Harvard College.

Within the last few years the energetic director of the Harvard College Observatory has been enabled to extend his operations by the erection of a well-equipped observatory in the clear air of Arequipa, Peru, spectroscopic and other data on a uniform plan for the whole celestial vault being thus secured. Prof. PICKERING has, in fact, developed the photographic side of his work into a wonderful detective force, so perfectly organized that no new star of reasonable brightness can escape detection, and no important change in a known star go unrecorded. The munificent gifts to the Harvard Observatory have thus, in Prof. PICKERING'S hands, been put to the best possible uses.

The work of the Lick Observatory is also largely photographic. Here, the great refractor has been employed with the

greatest success by Prof. CAMPBELL in photographing the spectra of nebulae and bright line stars. More recently special attention has been given to the photographic determination of stellar velocities in the line of sight, with the result that a dozen or so of spectroscopic binaries have already been detected, *Polaris* and *Capella* being among the most interesting systems thus recognized. Quite recently marvelous results have been obtained by Prof. KEELER in photographing the forms of nebulae with the Crossley reflector. The director's report for the year ending September 1, 1899, indicates a remarkable state of activity among the comparatively small staff of this observatory. The success of these observers is doubtless in some measure due to the wisdom displayed in the limitations which they have set to their work. A well-defined programme, and concentration upon it, appears to be the policy adopted, and the truly scientific spirit which controls their investigations is exhibited by the following remarks from Prof. KEELER's last report: "Comets which are bright enough to be easily seen at the leading observatories receive only occasional attention, while comets which, by reason of their faintness or unfavorable position, are difficult of observation, are followed as closely as possible. . . . The Lick Observatory makes the most of its natural advantages; and extended theoretical researches, which can be made as well in a city as at a fine observing-station, do not form part of our general plan." In this way the output of useful observations is greatly increased, and the co-ordination of different facts can be carried on by workers generally. The same spirit prevails at Harvard Observatory, where "precedence has been given to physical work, since less attention is paid to such work elsewhere," and the photographic records there accumulated have been placed at the service of any one properly qualified to discuss them.

The Yerkes telescope, in the hands of BURNHAM, BARNARD, and HALE, has already been very productive. One of the most important pieces of work undertaken here is the photographic registration of the spectra of the *Piscian* (III δ) stars; and the wealth of detail recorded in such difficult objects is truly remarkable.

But it is by no means only in observatories furnished with giant telescopes that astronomical science has been advanced. Admirable work has also been done in unpretentious establish-

ments, and, indeed, with no observatories at all. GOULD'S investigation of the Milky Way and the distribution of stars is a case in point, and, to take another example, a vast amount of energy has been expended in perfecting the *American Ephemeris* and *Nautical Almanac*. CHANDLER'S masterly investigations of the variations of terrestrial latitude also demand separate mention.

Terrestrial researches bearing on astronomical phenomena have not been neglected. NEWCOMB and MICHELSON'S determinations of the velocity of light are classical examples, and among more recent work reference may be made to ROWLAND'S determinations of the origins of a vast number of Fraunhofer lines, and to HUMPHREY'S and MÖHLER'S investigations of the displacement of spectrum lines due to pressure.

It will be seen, even from this incomplete statement, that the output of astronomical work in America has been very great, and there is every indication that it will go on increasing. The rapid development is doubtless due to various causes, not least among them being the unstinted support given by private benefactors. The American astronomers undoubtedly also owe a great debt to their opticians and engineers, the Lick and Yerkes refractors, with their apertures of thirty-six and forty inches respectively, being the crowning triumphs of the instrument-makers. Messrs. ALVAN CLARK'S telescopic object-glasses have long been justly held in high estimation all over the world, and the skill of Messrs. WARNER & SWASEY has been fully equal to the task of successfully mounting their mammoth productions.

Some of the success of the Americans may perhaps be attributed to their wise selection of sites for their instruments, when they have been free to exercise their judgment. The Lick Observatory, at an elevation of 4,000 feet, is favored with exceptionally good atmospheric conditions, and the sites of the Yerkes and various other observatories were only decided upon after very careful trials.

Instrumental equipment and good climate, however, are not the only requisites for a successful observatory. Much depends upon the men at the little ends of the telescope tubes, and, we may add, upon the men at their desks or in their laboratories, who bring their minds to bear upon the explanation or utilization of the phenomena observed, besides suggesting further observa-

tions. The training of astronomers is therefore of as much importance as the provision of instruments. Fortunately, America can boast of unparalleled facilities for this necessary training. Students' observatories abound, and in many cases instruction of the most advanced character is obtainable. Of elementary instruction it is scarcely necessary to speak; but American students are to be congratulated if the teaching generally is on such enlightened lines as those indicated in Miss BYRD'S "Laboratory Manual of Astronomy," and Prof. TODD'S "New Astronomy." A most valuable paper, by Prof. E. S. HOLDEN, on the teaching of astronomy in primary and secondary schools and in the university has recently been published.* During the early years of a child's school life, the lessons must necessarily be simple; and Prof. HOLDEN gives an extremely suggestive sketch of the methods which should be followed, bearing in mind that "the main point is to open the eyes and mind, and the Sun and stars are convenient for the purpose." To the teachers of astronomy in secondary schools Prof. HOLDEN also gives many valuable hints. Here astronomy is to be regarded as an "information study," as well as an educative one, and suggestions as to simple apparatus to facilitate the teaching are given.

From our present point of view, however, the most interesting part of Prof. HOLDEN'S paper is that referring to the courses of instruction in astronomy offered by some of the American universities and colleges. Particulars are here given of the instruction carried on in fifteen institutions, and they illustrate in the most satisfactory manner the advantages enjoyed by the American student who wishes to acquire an extended knowledge of the subject. The courses are in several cases remarkably comprehensive, and in five of them astrophysics takes an important place in the curriculum. In every case there appears to be an adequate supply of instruments and observatories, and for students desiring to specialize there are abundant opportunities of entering even the best observatories.

The course of the University of Chicago is perhaps the most complete, but the syllabus is too long for quotation; suffice it to say that it includes every department of theoretical and practical astronomy, the astrophysical instruction being carried

* "Report of the Commissioner of Education, 1897-98." Vol. I, p. 869. (Washington, 1899.)

on at the Yerkes Observatory by the distinguished staff of resident professors and observers. The director of the Yerkes Observatory some time ago made the following statement as to the relation of that establishment to the work of students: "After completing the necessary preliminary work at Chicago, students who desire to devote special attention to observational astronomy or to astrophysics are admitted to the Yerkes Observatory at Lake Geneva, where they are given every possible facility. In addition to pursuing the courses of instruction enumerated in the *Annual Register* of the University of Chicago, students at the observatory may take part in the regular work of research. As soon as they have had sufficient preliminary training, they are encouraged to undertake original investigations of their own." From other notices we gather that this privilege is not restricted to students from Chicago.

At the University of California also an admirable course of astronomy is offered, one item of which may be quoted as illustrating the attention given to practical work: "4 A. Practical astronomy. Lectures and observatory work. Navigation and nautical astronomy. Practical work in the observatory. Six hours observatory, first half. Three hours lecture and six hours observatory, second half."

The University possesses an excellently equipped students' observatory, in addition to the world-famous establishment on Mount Hamilton. Graduates of the University, or indeed of other universities of equal standing, are received at the Lick Observatory to pursue a higher course of instruction in astronomy; every facility consistent with the scientific work of the establishment will be given them, and they will usually be assigned as assistants to some of the astronomers. An illustration of the bond between the greater and lesser establishments is afforded by the recent computation at the students' observatory of the elements of a comet from observations telegraphed by the astronomers at Lick. (*Pub. Ast. Soc. Pac.*, Vol. XI, No. 70, p. 190.)

From the information which Prof. HOLDEN has collected, we gather that special students of promise have also the privilege of entering into the regular work of the observatories at Harvard College, and the Universities of Yale, Michigan, Virginia, Wisconsin, and Pennsylvania.

The special value to the student of this association with the staff of an observatory is admirably stated by Prof. HOLDEN in a

report on the Lick Observatory, from which he makes the following quotation: "No institution in the world is better fitted to give such instruction, and there is a special impetus to be gained in an observatory which is regularly pursuing work of discovery and research. The student comes directly into the current, and learns far more by observation of the methods of others than by the study of text-books. He can take part in the regular work of the observatory also." This happy arrangement is not only beneficial to the student. Prof. HOLDEN further remarks: "It is a great advantage to the University as a whole to count among its members a considerable number of active and ambitious young men who are able to work with some independence to advance science, and not merely to acquire what is already known. They set a standard of scholarship to all the undergraduates. Such students can take a useful part in the actual observations of every day as assistants, and after some practice they become valuable aids in our work of computation and observation, and supplement the permanent force of the observatory in an important degree."

No wonder that with advantages like these there is an adequate supply of highly-trained young astronomers capable of fully developing the great resources which the scientific spirit of wealthy Americans has placed at their disposal. It appears to us that it is precisely for want of opportunities for securing the necessary technical training to future observers that the astronomical development of our own country proceeds less rapidly than that of America. While it is possible to obtain a certain amount of tuition in spherical astronomy, and here and there a modicum of practical instruction in the older branches of the subject, facilities for the study of astrophysics are almost completely lacking, and it is a deplorable fact that the universities are especially deficient in this respect.

Under the Science and Art Department, a general study of astronomy is encouraged, but the subject is incorporated with a variety of other subjects under the comprehensive title of Physiography, and no separate certificate for astronomy is granted.

At the universities, astronomical teaching appears to remain in much the same position as the teaching of chemistry and physics before the introduction of practical work in those subjects, the prevailing idea apparently being that if a mathematician can be placed at the head of affairs in an observatory, it matters

little who makes the actual observations or whether observations are made or not. There can be little doubt that means exist for establishing schools of astronomy comparable with those which have arisen for other branches of science, and we sincerely hope that the need for serious attention to practical teaching in astronomy will soon be recognized.

So far as we know, there is only one institution in Great Britain where any attempt is made to give practical instruction in astronomical physics, and even in this case the greater part of the instruction is necessarily of a somewhat elementary character, in consequence of the small amount of time available for the subject.

It is a natural consequence of our inadequate provision for technical education in astronomy — more particularly in the newer branches — that vacancies in our observatories must be filled by observers who have still to make practical acquaintance with the work expected of them. Much loss of time and apparent inactivity is the result.

It may be urged that benefactors of the science of astronomy are less numerous here than in America, but the generous gifts of Dr. F. McCLEAN to Cambridge University and the Cape Observatory, and of Sir HENRY THOMPSON to the Royal Observatory, Greenwich, remind us that they are not wholly wanting. Besides, there are already numerous observatories scattered throughout the country which might be made more productive by putting them in the hands of observers who have received adequate training. Public interest in astronomy is by no means absent, and British observatories would, perhaps, receive a much increased measure of support if it were not for the possible impression that the best work can only be done in America, and that instruments of the largest size are alone useful.

A HANDBOOK OF ASTRONOMICAL INSTRUMENTS.

Handbuch der Astronomischen Instrumentenkunde. Von Dr. L. AMBRONN, Professor an der Universität und Observator an der königl. Sternwarte zu Göttingen. Mit 1185 in den Text gedruckten Figuren. Berlin, Verlag von JULIUS SPRINGER, 1899. (Price, \$15.00.)

Dr. AMBRONN's two large volumes form an encyclopædia of astronomical instruments in which the whole of the instrument-

maker's art, from the shaping of the slot in a screw-head to the construction of a modern great equatorial, is clearly described and illustrated with an abundance of excellent figures. The work is not wholly descriptive, however, since theoretical discussions of many subjects, such as the determination of the periodic errors of screws and of the graduation errors of circles, are freely introduced.

The first volume, containing five hundred pages, is devoted to accessory apparatus, clocks, and the separate parts of instruments. We find here an account of screws, levels, artificial horizons, axes and circles, mirrors, eye-pieces, etc. An interesting feature of the book is that the descriptions are not confined to instruments of the present day. Older forms of instruments, progenitors of modern types, are treated at some length, and illustrated when the historical development of the subject makes their consideration desirable. Thus we find, in the first volume, an account of various early applications of the plumb-line and of early forms of clocks.

The second volume, containing 776 pages, is devoted to complete instruments of every kind—meridian-circles, universal instruments, chronographs, equatorials, etc., but it is impossible to give here an adequate idea of the contents of this very complete treatise.

Dr. AMBRONN'S volumes are, on the whole, a manual of German practice; but national bias in such a work is inevitable, and in this case is the less to be regretted, since the Germans have always excelled in the art of instrument-making. Still, readers of other nationalities will notice omissions which they may be inclined to regard as important. No American, perhaps no Englishman, would write a treatise on screws in which ROWLAND'S method of making screws of precision, as described in the *Encyclopædia Britannica*, is not mentioned. In the chapter on clocks the name of DENT does not occur. Sir E. BECKETT'S gravity escapement, which is so widely used in England and America, and which is probably the best of its kind, is not described or even referred to. On the other hand, an English or American writer would certainly overlook many of the escapements described and illustrated in the same chapter, as they are hardly used outside of Germany.

On reading the author's comments on different forms of instruments, in which complicated devices for manipulation or adjust-

ment are almost invariably spoken of in terms of approbation, one cannot avoid the impression that simplicity and rudeness are too generally regarded as synonymous, while elaborateness is regarded as essential to the highest precision. This attitude is noticeable in the comments on American instruments, of which, it seems to the reviewer, the author has failed to grasp the characteristic features. These are, briefly, the care bestowed on essentials, and the indifference with which minor details are treated. One can imagine the disfavor with which the author would view the rough-looking yet effective instruments of the Harvard College Observatory. The lover of instruments may like to see his apparatus beautiful and perfectly finished in all its parts, but he should be willing to concede that perfection of finish is not essential to performance. There are some instrument-makers, like the late Mr. DENT, the celebrated English clock-maker, who finish the non-essential parts of their instruments with the greatest care, in deference to the wishes of their patrons, though personally holding the opinion that in so doing they are merely wasting time. In America the rough-looking instrument is not generally objected to, if its proportions are correct, and if it works well.

Appliances for the adjustment and manipulation of instruments do not always tend to increase the accuracy of observation, and sometimes are even prejudicial to it. For instance, the clamp and tangent-screw ordinarily attached to graduated circles are not used by skilled observers with the micrometer. The elaborate mechanical adjustments on some forms of level-tries are, possibly, conveniences, but they do not (as is implied by the remarks on p. 62) add anything to the precision of the observations. The essential feature of this instrument is stability, including freedom from the effect of temperature changes.

It is true that (as stated on p. 1049) the Americans have not advanced beyond the single-pen form of chronograph. Their preference for this form does not, however, arise from prejudice or non-progressiveness, but from the consideration that even with a single pen the record is still more precise than the observation itself. The use of a double set of prickers, by which the record of an observation can be read to a few thousandths of a second, would seem to be as unnecessary as seven-place logarithms for computing the time of sunrise.

If the details of many American instruments might be more carefully fitted and finished, it may be said of many German

instruments that the harmony of the general design has been to some extent lost sight of in the attention paid to the component parts. The weight of metal is often in the wrong place, and the instrument has an awkward appearance. An exception should be made here of the graceful instruments of REPSOLD. In the judgment of the reviewer, there is no small equatorial among the many illustrated in Dr. AMBRONN'S book which so fully satisfies the sense of mechanical proportion as the WARNER & SWASEY mounting on page 1156.

The mounting of a modern great equatorial is really a problem in engineering, and if one may venture a criticism of the fine large equatorials of recent European construction, it is that they have been treated rather from the standpoint of the instrument-maker. With respect to the numerous attachments of large equatorials, it is certain that, in the case of the Lick telescope, at least, experience has shown some of them to be unnecessary; and this is a point of no small importance, since these attachments are often very expensive. The quick motions for operating the Lick telescope from the top of the pier are indispensable, but the slow motions at the same place are never used, and, since they somewhat increase the friction of the polar axis, they could well be dispensed with. The microscope and reflectors for reading the finely divided hour-circle from the eye-end have never once been used, and the declination microscopes at the eye-end very seldom, so that these attachments have been removed. In fact, on duly considering the matter, we find that the fine circles of a great equatorial have only one use — to perfect the adjustment of the polar axis,—and provision for reading them from the head of the pier is sufficient for this, and therefore for every purpose.

By far the least satisfactory chapter in the book is the one on spectroscopic apparatus, which is compiled, not very judiciously, from various sources. The instruments and appliances to which the greater part of the space is devoted are old and of small efficiency, while really efficient instruments, for which all the conditions of use have been carefully studied, are passed over lightly, or only referred to in foot-notes. It is true that the former instruments might have been introduced for their historical interest, but the reader is left to suppose that they are still valuable for purposes of research. The Potsdam spectrograph, which has only recently been superseded by more efficient instruments, has about a page. It is a pity that the MILLS spec-

trograph of the Lick Observatory, Professor VOGEL's new Potsdam spectrograph, or Dr. GILL's spectrograph for the Cape Observatory, could not have been included; but for this the book was published just a little too soon.

A brief statement of the theory of resolving power, as developed by Lord RAYLEIGH, would have been very useful as a guiding principle, which is totally lacking in the chapter, and would have shown at once the practical uselessness of some of the forms of spectroscopes described.

The chapter on photometers, on the other hand, is especially valuable. Here the different forms of photometers used in astrophysical research are brought together in a most convenient form for reference.

Occasional mistakes can be found. Fig. 1160, which purports to represent the moving floor of the Lick Observatory, is a design which was proposed, but not adopted; but such mistakes as this would naturally be made by one who is not personally familiar with all the instruments described, and they are few in number. It is hardly necessary to say that Dr. AMBRONN's valuable book should be found in the library of every observatory.

J. E. KEELER.

PLANETARY PHENOMENA FOR JULY AND AUGUST,
1900.

BY MALCOLM McNEILL.

JULY.

The Earth is in aphelion at 4 A. M., July 2d, P. S. T.

Mercury is an evening star throughout the month, and comes to greatest east elongation on the morning of July 4th. During the first half of the month it will set an hour or more after sunset. After the middle of the month, it will be too close to the Sun to be seen, and it reaches conjunction with the Sun on the night of July 31st-August 1st. The present elongation, 26° , is greater than that in March, by 8° , as it comes very near the time when the planet is in aphelion, July 13th, while that in March was about the same interval from perihelion. The fact that at the July elongation the planet is south of the Sun, while the reverse was true in March, makes a considerable offset in the

interval between the setting of the Sun and the planet; but, on the whole, the July elongation affords the best opportunity of the year for evening observation.

Venus passes inferior conjunction with the Sun on the morning of July 8th, and changes from an evening to a morning star. It is still moving westward among the stars, and this motion, combined with the eastward motion of the Sun, causes a rapid separation of the bodies, so that by July 20th the planet rises more than an hour before sunrise, and about twice that on July 31st, and it will be an easy object to see. On July 29th the planet begins to move eastward again among the stars.

Mars rises earlier, and has begun to increase in brightness. It moves 23° eastward among the stars in *Taurus*, and on July 10th passes about 5° north of the first-magnitude red star *Aldebaran*.

Jupiter remains above the horizon until after midnight. It moves westward about 1° until July 29 in the constellation *Scorpio* near the third-magnitude star β *Scorpii*, the time of nearest approach being July 5th, when the planet is $15'$ south of the star.

Saturn is in fine position for observation, being above the horizon until long after midnight. It moves westward about 2° in the constellation *Sagittarius*, north and west of the handle of the Dipper. On the night of July 10th, it will again be occulted by the Moon, the occultation occurring before midnight in the Eastern States, and earlier in the evening in the Western States.

Uranus is still near *Jupiter* in *Scorpio*, about 7° east.

Neptune moves about 1° east near the border line of *Gemini* and *Taurus*.

AUGUST.

Mercury passes inferior conjunction at the beginning of the month, and moves rapidly out toward greatest west elongation, which it reaches on August 19th. After August 10th, it rises more than an hour before sunrise, and may be seen in the early morning twilight.

Venus is morning star. It moves eastward among the stars about 16° , while the Sun moves nearly double that amount; so the distance between the two is increased about 12° , and the interval between the rising of the planet and sunrise increases to about three and one half hours. The planet will be very brilliant all through the month, reaching the maximum on August 14th, and may be seen by daylight with the naked eye.

Mars rises half an hour earlier than during July. It moves about 22° eastward during the month, from the constellation *Taurus* into *Gemini*, and at the end of the month is a little west of *Castor and Pollux*, the three making nearly a right-angled triangle, with the right angle at *Pollux*, the southern star.

Jupiter remains in good position for observation in *Scorpio*, not setting until late in the evening. It resumes its eastward journey among the stars at the end of July, and during August moves about 2° . It again passes the third-magnitude star β *Scorpii* on August 22d, the southward distance of the planet being $26'$, nearly twice as great as it was at the July approach. Its eastward path will be in general about half a degree south of the line it pursued while retrograding.

Saturn remains in *Sagittarius*, moving westward about 1° , and is above the horizon until nearly morning. As the rings are now at about their maximum opening, the planet presents perhaps its finest view in the telescope.

Uranus is still in about the same position, nearly stationary in *Scorpio*. The motion of *Jupiter* is bringing it back toward *Uranus*, and at the end of the month the latter is about 6° east of the former.

Neptune moves about 1° east on the border of *Taurus* and *Gemini*.

JULY-AUGUST, 1900.

PHASES OF THE MOON, P. S. T.

First Quarter . . .	July 4, 4 ^h 14 ^m	P. M.
Full Moon	July 12, 5 22	A. M.
Last Quarter . . .	July 18, 9 31	P. M.
New Moon	July 26, 5 43	A. M.
First Quarter . . .	Aug. 3, 8 46	A. M.
Full Moon	Aug. 10, 1 30	P. M.
Last Quarter . . .	Aug. 17, 3 46	A. M.
New Moon	Aug. 24, 7 53	P. M.

THE SUN.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	6 ^h 40 ^m	+ 23° 8'	4 ^h 40 ^m A. M.	12 ^h 4 ^m P. M.	7 ^h 28 ^m P. M.
11,	7 21	+ 22 9	4 45	12 5	7 25
21,	8 1	+ 20 32	4 53	12 6	7 19
Aug. 1,	8 45	+ 18 5	5 3	12 6	7 9
11,	9 23	+ 15 21	5 11	12 5	6 59
21,	10 0	+ 12 12	5 21	12 3	6 45
31,	10 37	+ 8 43	5 30	noon	6 30

*Publications of the**MERCURY.*

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	8 ^h 30 ^m	+ 19° 31'	6 ^h 44 ^m A. M.	1 ^h 53 ^m P. M.	9 ^h 2 ^m P. M.
11,	9 1	+ 15 20	6 52	1 45	8 38
21,	9 5	+ 12 40	6 25	1 9	7 53
Aug. 1,	8 38	+ 13 25	5 14	noon	6 46
11,	8 21	+ 16 18	4 7	11 4 A. M.	6 1
21,	8 48	+ 17 33	3 49	10 50	5 51
31,	9 52	+ 14 30	4 25	11 15	6 5

VENUS.

July 1,	7 25	+ 19 18	5 40 A. M.	12 48 P. M.	7 56 P. M.
11,	6 58	+ 17 54	4 40	11 43 A. M.	6 46
21,	6 37	+ 17 5	3 43	10 42	5 41
Aug. 1,	6 32	+ 17 0	2 54	9 53	4 52
11,	6 43	+ 17 22	2 25	9 25	4 25
21,	7 5	+ 17 43	2 7	9 8	4 9
31,	7 36	+ 17 42	1 58	8 59	4 0

MARS.

July 1,	4 4	+ 20 32	2 14 A. M.	9 27 A. M.	4 40 P. M.
11,	4 33	+ 21 51	2 0	9 18	4 36
21,	5 3	+ 22 49	1 46	9 8	4 30
Aug. 1,	5 35	+ 23 30	1 33	8 58	4 23
11,	6 4	+ 23 45	1 19	8 46	4 13
21,	6 33	+ 23 41	1 9	8 35	4 1
31,	7 1	+ 23 18	1 0	8 24	3 48

JUPITER.

July 1,	16 1	— 19 49	4 33 P. M.	9 23 P. M.	2 13 A. M.
Aug. 1,	15 56	— 19 43	2 26	7 16	12 6
Sept. 1,	16 3	— 20 10	12 34	5 22	10 10 P. M.

SATURN.

July 1,	18 5	— 22 28	6 48 P. M.	11 27 P. M.	4 6 A. M.
Aug. 1,	17 57	— 22 32	4 37	9 16	1 55
Sept. 1,	17 53	— 22 36	2 32	7 11 P. M.	11 50 P. M.

URANUS.

July 1,	16 31	— 21 49	5 10 P. M.	9 52 P. M.	2 34 A. M.
Aug. 1,	16 27	— 21 43	3 6	7 48	12 30
Sept. 1,	16 27	— 21 43	1 4	5 46	10 28 P. M.

NEPTUNE.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	5 ^h 48 ^m	+ 22° 14'	3 ^h 52 ^m A. M.	11 ^h 12 ^m A. M.	6 ^h 32 ^m P. M.
Aug. 1,	5 52	+ 22 14	1 54	9 14	4 34
Sept 1,	5 56	+ 22 14	11 55 P. M.	7 15	2 35

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

II, R,	July 1,	7 ^h 41 ^m P. M.	II, D,	Aug. 2,	5 ^h 3 ^m P. M.
I, R,	1,	11 33	II, R,	2,	7 31
I, R,	3,	6 2	I, R,	2,	8 9
III, D,	6,	6 59	II, D,	9,	7 41
III, R,	6,	8 50	I, R,	9,	10 4
II, R,	8,	10 18	II, R,	9,	10 9
I, R,	9,	1 28 A. M.	II, D,	16,	10 18
I, R,	10,	7 56 P. M.	II, R,	17,	12 47 A. M.
III, D,	13,	10 57	III, D,	18,	6 50 P. M.
III, R,	14,	12 50 A. M.	III, R,	18,	8 50
II, R,	16,	12 56	I, R,	25,	8 22
I, R,	17,	9 51 P. M.	II, R,	27,	4 43
I, R,	24,	11 46			
II, R,	26,	4 53			
I, R,	26,	6 14			



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DISCOVERY OF A NEW ASTEROID, 1899 FD, WITH THE CROSSLEY REFLECTOR.

The region of HINDS's variable nebula in *Taurus* was photographed with the Crossley reflector on the night of December 6, 1899, with an exposure of four hours, and on the negative, when it was examined the next morning, there was found a very fine faint line, which was recognized as the trail of an asteroid.

Owing to a defect in the film, the position of the asteroid could not be determined accurately on the first plate, and another photograph was made on the night of December 9th. The next observation was made on December 26th. From these two positions, circular elements were computed by Mr. CODDINGTON. These elements represented the motion of the asteroid with much accuracy, owing to the fact, subsequently discovered, that the eccentricity of the orbit is very small.

As the telescope was constantly in use for other purposes, a third observation was not obtained until the night of January 19th. On this night the 36-inch refractor was available for visual observations, and a search was made for the asteroid with the aid of the photograph just taken. It was, however, not certainly visible, and its magnitude was taken to be 17.

The following positions were deduced from measurements of the plates by Mr. CODDINGTON and Mr. PALMER :

1899-00.	Mt. H. Mean Time.	App. R. A.	App. Dec.
Dec. 9.	9 ^h 29 ^m 36 ^s	4 ^h 13 ^m 52 ^s .58	+ 19° 14' 51".9
26.	8 11 22	4 1 11.01	+ 19 2 22.2
Jan. 19.	7 53 35	3 54 49.32	+ 19 15 30.7

From these observations the following elliptic elements were computed by Mr. PALMER, and independently by Mr. PHIPPS, of the Students' Observatory, Berkeley.

* Lick Astronomical Department of the University of California.

Epoch, 1900 Jan. 0.0, Berlin M. T.

$$\begin{array}{llll} M = 296^{\circ} & 42' & 7''.9 & \phi = 1^{\circ} \ 13' \ 23''.3 \\ \omega = 46 & 39 & 31.5 & \mu = 736''.622 \\ \Omega = 92 & 44 & 39.0 & \log a = 0.455174 \\ i = 3 & 13 & 15.8 & m_0 = 16.7 \ g = 13.1 \end{array}$$

The values of M and ω are subject to considerable uncertainty, on account of the small eccentricity. The asteroid is the smallest that has yet been found. J. E. K.

NEW DOUBLE STARS.

My search for new double stars has resulted in the finding of thirty-seven new pairs (all under 5") in the first four months of the present year. Twenty-five of these have distances of less than 2", thirteen are under 1", and five of them are very close. In general the 12-inch has been used for this work, but on two or three nights when the seeing did not admit of the use of high powers, some sweeping was done with the 36-inch telescope.

A few of the pairs found possess sufficient interest to warrant their publication here in advance of the complete list. These are:—

A. G. Cambridge 2997.

$$6^h \ 3^m \ 22^s + 29^{\circ} \ 15'.$$

1900.201	343 ⁰ .6	0".58	7.5 - 8.5	3	12
.204	344.0	0.58	7.5 - 9.0	3	12
.209	348.3	0.46	7.5 - 8.5	3	36
.291	342.4	0.49	7.5 - 8.5	3	36
1900.23	344 ⁰ .6	0".53	7.5 - 8.6		

Found with the 12-inch on March 14th, while looking for the following star:—

A. G. Cambridge 3025.

$$6^h \ 5^m \ 20^s + 28^{\circ} \ 47'.$$

1900.190	284 ⁰ .8	0".43	9.0 - 9.5	3	36
.193	288.4	0.52	8.7 - 9.3	3	36
.209	293.3	0.52	8.5 - 9.2	3	36
1900.20	288 ⁰ .8	0".49	8.7 - 9.3		

Found with the 36-inch on March 10th.

*Publications of the**SD* $-3^{\circ} 1576$. $6^h 40^m 19^s - 3^{\circ} 52'$.*AB.*

1900.127	235°.4	0".86	9.0 - 12.0	4	12
.152	238 .2	1 .03	8.5 - 13.0	4	36
<u>.245</u>	<u>233 .6</u>	<u>1 .01</u>	<u>9.0 - 12.5</u>	<u>3</u>	<u>36</u>
1900.17	235°.7	0".97	8.8 - 12.5		

AC.

1900.152	320°.0	4".94	- 14.5	4	36
<u>.245</u>	<u>320 .6</u>	<u>5 .03</u>	<u>- 14.5</u>	<u>3</u>	<u>36</u>
1900.20	320°.3	4".98	- 14.5		

The close pair was found with the 12-inch on February 15th, and the third star added with the large telescope.

SD $-3^{\circ} 1603$. $6^h \quad \quad \quad - 3^{\circ}$

1900.127	147°.2	4".07	7.5 - 8.2	3	12
.130	145 .4	4 .02	7.5 - 8.2	2	12
<u>.152</u>	<u>147 .8</u>	<u>4 .21</u>	<u>7.8 - 8.4</u>	<u>4</u>	<u>36</u>
1900.14	146°.8	4".10	7.6 - 8.3		

This star is interesting mainly because it has not been seen before as a double star. This may be due merely to chance, or the pair may have been much closer in the early part of the century when this region of the sky was systematically examined by STRUVE and HERSCHEL.

DM $+72^{\circ} 550$. $11^h 48^m 44^s + 72^{\circ} 29'$.

1900.245	205°.5	0".26	7.5 - 8.0	3	36
<u>.346</u>	<u>210 .5</u>	<u>0 .30</u>	<u>7.0 - 8.0</u>	<u>3</u>	<u>36</u>
1900.29	208° 0	0".28	7.2 - 8.0		

Found with the 36-inch on March 30th, while measuring β 794, which is 2° farther north.

R. G. AITKEN.

A REMARKABLE METEOR TRAIN.

A remarkable meteor train was observed at Mt. Hamilton on the night of March 29th. The meteor itself was seen in the east at about $9^h 55^m$ by two of the ladies at the Lick Observatory, who

described it as very brilliant and surrounded by a bright glow, or halo. It had very little motion, and lasted an unusually long time.

On disappearing, the meteor left a very bright train, which at 10^h 30^m looked like the tail of a bright comet. It drifted slowly westward, passing just above the pole-star, and disappeared in the northwest at about 11^h 30^m. Unfortunately, all the spectroscopes suitable for observing the bright cloud as it passed across the sky were dismantled, in preparation for the solar eclipse.

According to notices in the newspapers, the meteor was observed at least as far eastward as Utah. J. E. K.

MEASURES OF TWO DOUBLE STARS—PROBABLY NEW.

B.D. + 13° 3607				Seeing.	
1900.208	3°.8	3".46	8.8	10.	3
.285	3.8	3.32	8.8	10.5	2—3
1900.246	3°.8	3".39	8.8	10.2	

B.D. + 14° 3502					
1900.208	149°.0	1".90	8.5	8.6	3
.285	148.7	1.86	8.8	9.0	2—3
1900.246	148°.8	1".88	8.6	8.8	

There is a 13th-magnitude star at 51°.4, 14".9.

B.D. + 13° 3607 was used as the comparison star for an observation of Comet *c* 1899 on December 6th, when it was noticed to be double. Later in setting for it, B.D. + 14° 3502 accidentally came into the field and was noticed to be double also.

The above observations were made with the 36-inch refractor using a power of 520. These stars could not be identified from any of the principal catalogues.

C. D. PERRINE.

MT. HAMILTON, April 17, 1900.

PUBLICATIONS OF THE LICK OBSERVATORY, VOL. IV.

The complete edition of Volume IV of the *Lick Observatory Publications* has been received from the State Printing Office, and will be distributed as soon as practicable. The volume contains meridian-circle observations of 310 standard stars, with a very complete discussion of results, by Professor R. H. TUCKER. Of these stars, 157 are from the *American Ephemeris*, the *Connaissance*

sance des Temps, and the *Berliner Jahrbuch*, and 153 are from the *Berliner Jahrbuch*.

Considerable space is devoted to a description of the instrument employed, since this is the first of the Lick Observatory volumes in which meridian-circle work has appeared. J. E. K.

PRELIMINARY ACCOUNT OF THE RESULTS OBTAINED BY THE
CROCKER ECLIPSE EXPEDITION OF THE
LICK OBSERVATORY.

Advices received from Professor CAMPBELL, in charge of the Crocker Eclipse Expedition, at Thomaston, Georgia, show that the party had a narrow escape from clouds on the day of the eclipse. The sky was cloudy at sunrise, but it cleared a little later in the morning. Ten minutes before totality large clouds were drifting rapidly toward the Sun, and one minute after third contact the Sun was obscured. Fortunately the sky around the Sun was clear during totality. Mr. CAMPBELL and Mr. PERRINE were aided by fourteen assistants, among whom was Mr. H. D. CURTIS, formerly of the University of the Pacific.

Mr. CAMPBELL reports that the photographs obtained with the 40-foot camera are very fine. The connection between the streamers of the inner corona and the prominences, which was brought out so beautifully on the pictures obtained in India with the same apparatus, is not so apparent on these negatives, but traces of it can probably still be found. The photographs obtained with the smaller cameras are of various degrees of excellence; some are good, and some poor. On the negatives obtained with the Floyd telescope, on slow plates, the streamers of the corona can be traced from three to four solar diameters, or as far as the eye could trace them during the eclipse. The results with the spectroscopic apparatus were less successful. One of the plate-driving clocks, after performing perfectly during every rehearsal, failed at the critical moment. An exposure to the spectrum of the corona was, however, obtained during totality. The observations of contacts were carried out according to the programme.

Notwithstanding the few partial failures recorded above, the success of the party in carrying out its extensive and complicated programme is a source of satisfaction to the Observatory and to all interested in its work. It is also gratifying to record the fact that, so far as known at present, successful observations were secured by all the parties in the line of the eclipse. J. E. K.

ASTRONOMICAL TELEGRAMS.

(Translations.)

To the Lick Observatory, CAMBRIDGE, MASS., April 10, 1900.
Mt. Hamilton. (Received 4 P.M.)

Professor KREUTZ telegraphs as follows:—

“From a discussion of spectrograms, BELOPOLSKY has found the time of rotation of *Venus* to be short. Report sent out by Professor BACKLUND, Director.”

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., April 30, 1900.

To Professor JAMES E. KEELER, (Received 2:25 P.M.)
Lick Observatory.

Arequipa telegraphs that on April 26, 21^h G. M. T., the position of *Eros* was 15' preceding and 8' south of the place predicted by JONES's ephemeris.*

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., May 14, 1900.

To Professor J. E. KEELER: (Received 2:10 P. M.)

Arequipa cables † that the correction to JONES's ephemeris of *Eros* is zero in both Right Ascension and Declination.

(Signed) E. C. PICKERING.

* See *Popular Astronomy*, January, 1900, p. 41.

† This message corrects the one received on April 30th. Professor PICKERING writes that the error perhaps arose from assuming that the ephemeris was computed for noon instead of midnight, as the corrections given in the first message are almost exactly half the daily motion of *Eros*.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley California.

A meteor of unusual size and brilliancy fell on the evening of Monday, April 16th, at about 7 P. M., and was seen from Mt. Hamilton as far north as Ashland, Oregon. Unfortunately none of the astronomers at the Lick Observatory witnessed the phenomenon, but one of the ladies who chanced to be standing near a window facing to the north saw it, and described it as a fire-ball many times brighter than *Venus*. It was first seen a little north of the zenith and east of the meridian, and moved slowly northward, disappearing when about 20° from the horizon. Before it disappeared, it separated into two parts, one of which burst a second later with the appearance of a falling rocket. No explosion was heard, and no smoke-cloud was seen.

Newspaper reports show that the meteor was seen throughout the central and northern part of the State. At Chico its course was described as northward and downward. After traversing an arc of 45° it burst, and one large red ball of fire seemed to fly off at an angle from the original course. A small cloud of dense white smoke was visible for nearly half an hour.—*Chico Record*.

The Placer County *Leader* says: "A single ray shot upward at 45° to the west and a ball of fire shot downward at a right angle to it."

At Redding it was seen coming from the high northeastern sky, and passing toward the northwest, leaving a great trail of light and two small clouds of unusual brightness.

From Dunsmuir it was observed to flash out from the northeastern sky and pass toward the southwest. When it exploded, a report like the crack of a rifle was heard. An instant later there was a second explosion, fainter than the first, which completely shattered the meteor. The smoke-clouds were visible for some time afterward.

A letter received at the Lick Observatory from Mr. H. L. WHITED, at Ashland, Oregon, gives the following description:—"It appeared at exactly 7:05 P. M., April 16th, about S. S. E., at an altitude of about 30° , was visible about one second, apparently moving westerly and falling at an angle of 45° . To me it first appeared emerging from a cloud of white smoke with a short

trail falling, say 10° , then becoming invisible. We heard no explosion. The cloud of smoke remained in sight till dark, and was in diameter about five or six times as large as the moon."

Three star-catalogues that will be of great value to astronomers generally, and particularly to those engaged in micrometric work, have recently been issued.

The first of these is, in substance, the A. G. Catalogue for the zone $+35^{\circ}$ to $+40^{\circ}$ Declination, based on observations made at Lund, by N. C. DUNÉR and FOLKE ENGSTRÖM. The catalogue gives the separate observations of each star in the order of Right Ascension for the mean equinox of 1875.0.

The second is the Madras General Catalogue, prepared by J. MICHIE SMITH, the present Director of the Madras and Kodaikanal Observatories, and based on the observations made with the Madras meridian-circle between the years 1862 and 1887, under the direction of the late Government Astronomer, J. R. POGSON. This catalogue gives the positions for 1875.0 of 5,303 stars, including all the brighter stars to the fifth magnitude, inclusive, that could be observed at Madras, and many fainter zodiacal stars and stars south of -30° Declination.

The third is the Cape Catalogue for 1890.0, based on the meridian observations in the years 1885 to 1895 made at the Cape of Good Hope under the direction of H. M. Astronomer, DAVID GILL.

The working list for this catalogue included, besides several special lists of stars used in the latitude and longitude work of the Geodetic Survey, and as comparison-stars for heliometer work, etc., all the stars of fourth magnitude or brighter which could be conveniently observed from the Cape, and all stars additional to those likely to be required for future use in any of the National Ephemerides, and twenty-four southern circumpolar stars.

In addition to these general catalogues, the annual catalogue of the Greenwich meridian-circle observations for the year 1897 has just been distributed.

In No. 73 of these *Publications*, brief mention was made of a new elementary astronomy by Dr. E. S. HOLDEN, lately published by HENRY HOLT & CO. It may not be inappropriate, however, to give a little further attention to a book from which

many young people are likely to receive their first formal notions of the science of astronomy. When called upon to select a text-book for class use the experienced teacher considers the method in which the subject is presented more carefully than the actual facts contained in the book. The latter will be substantially the same for any science in all the better books of about the same date.

We may therefore dismiss the descriptive parts of the book — Parts II and III — with the notice already referred to and the additional statement that while these portions of the work are considerably compressed, the best results of modern research find a place, so far as they are appropriate to an elementary text.

The method in which the author has aimed to present the fundamental concepts of astronomy may be stated most simply by a quotation or two from his Introduction. He says:—

“The study of astronomy should lead the student to comprehensive ideas of the universe at large. . . . It should be the aim of the text-book and of the teacher to so marshal the most significant of the results of observation that the student may acquire such wide and general views. If he at the same time gains a luminous idea of the most important of the methods by which such results are reached, his teaching has been successful.”

“The book is addressed especially to pupils who are studying astronomy for the first time. The chief difficulties of such students are not due to the intrinsic complexity of the separate problems that they meet, but rather to their apparent want of connection one with another, and above all to the unfamiliarity of the student with the methods of reasoning employed. It is therefore necessary to treat each new topic with great clearness, and not to dismiss it until its relation to other topics has been at least partially apprehended. The important point is to present the subject in a way to convince and to enlighten the pupil, and this object can only be attained in a text-book by some repetitions and by avoiding undue brevity.”

A careful reading of the 268 pages that constitute the first part of the book will convince any one that Dr. HOLDEN has carried out his method with success, and that any student who has studied the work as it is intended to be studied, thinking out for himself answers to the suggestive questions which accompany each chapter, and making the simple observations as directed, will possess clear notions of the fundamental principles of astronomy.

There is an occasional minor blemish in the way of typographical errors. In general these are of no importance, but some pupils may be misled by the statement of the second law of diurnal motion of the stars (page 49): “The greater the star’s north-

polar distance, the larger is the [diurnal] circle.' This, of course, is true for all stars in the northern hemisphere; but from the context the pupil is likely to gather that it is true of the southern stars as well. We also notice that the author seems to prefer the French and English use of the north-polar distance as one of the co-ordinates of a star to the German and American practice of using the declination. But these are points of comparatively little consequence. In all essentials the book is one to be commended to teachers and pupils, as an excellent introduction in matter and method to the study of astronomy.

Telegrams received at the Lick Observatory and the Associated Press dispatches indicate that the total eclipse of the Sun was observed last Monday, May 28th, under unusually favorable conditions. The success of the Lick Observatory Expedition is noted elsewhere in this number. Mr. BURCKHALTER's programme* was carried out with complete success. His photographs will be looked for with special interest, as they should demonstrate conclusively the effectiveness of his method of controlling the relative lengths of exposure times for different portions of the corona.

A note on Miss O'HALLORAN's plans for observing the eclipse, both visually and photographically, from a station in Mexico, was accidentally omitted from the April number of these *Publications*.

We are sorry to learn that severe illness prevented Miss O'HALLORAN from carrying out her plans; but in spite of her illness, she viewed the eclipse through a pair of opera-glasses, and sends the following account of her observations:—

NEW ORLEANS, May 28, 1900.

The total eclipse of the Sun was observed here by me in an area of the sky that became entirely free from clouds only about fifteen minutes before second contact. It was then clear and blue. The inner corona became visible to the naked eye nearly one minute before totality, but it seemed shallow and inconspicuous even in the full gloom of eclipse, which resembled early twilight. The outer corona recalled that of January, 1889. The western wing, which extended about one degree from the Moon's limb, widened outwardly. The upper edge pointed almost directly to the planet *Mercury*. The entire outline was sharp and seemed of a streaky structure throughout. The eastern wing was not so distinct except at the base, and it tapered outwardly to invisibility before extending fully a

* See these *Publications* (No. 73, p. 64) for the details of the programme.

degree. The south polar rays were curved, pointed, and conspicuous. The fleecy white clouds seen half an hour after sunset convey an idea of the general tint of the corona.

Several other members of our Society were observers of this eclipse, among them Mr. COLTON, formerly of the Lick Observatory, who was in charge of the 40-foot photographic telescope of one of the parties sent out by the Naval Observatory.

In a subsequent number we hope to give some account of the scientific results obtained by the various observers.

Dr. WILLIAM LUTHER has been appointed Director of the Observatory at Düsseldorf to succeed his father, the late Robert Luther.

Director JAMES E. KEELER, of the Lick Observatory, has been elected a member of National Academy of Science.

At a recent meeting of the Board of Regents of the University of California, Professor ARMIN O. LEUSCHNER was made head of the Berkeley Astronomical Department. It was formerly a part of the department of Civil Engineering.

Professor GEORGE W. MYERS, Director of the Observatory of the University of Illinois, has resigned his position to take charge of the department of mathematics and astronomy in the Chicago Institute.

Dr. HENRY S. PRITCHETT has resigned his position of Superintendent of the United States Coast and Geodetic Survey to accept the position of President of the Massachusetts Institute of Technology.

PIAZZI SYMTH, a well-known astronomer and spectroscopist, for some time Astronomer Royal of Scotland, died on February 21st. He was born in Naples, and was named after the famous discoverer of *Ceres*.

The meetings of the Board of Directors, and of the Society, on June 9, 1900, were adjourned without the transaction of any business, owing to the lack of a quorum of members.

OFFICERS OF THE SOCIETY.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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JAMES EDWARD KEELER.



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JAMES EDWARD KEELER.

The Lick Observatory has lost an ideal Director. Astronomy has suffered a loss it can ill afford. Colleagues and friends widespread will miss a companionship which was simply delightful.

JAMES EDWARD KEELER was born in La Salle, Illinois, on September 10, 1857. RALPH KEELER, his first American ancestor, settled in Hartford in 1635. His father, WM. F. KEELER, was an officer of the original *Monitor* at the time of its engagement with the *Merrimac*. His mother (still living) is the daughter of HENRY DUTTON, former Governor of Connecticut, and Dean of the Yale Law School.

In 1869 the family removed from La Salle, Illinois, to Mayport, Florida. Here KEELER prepared for college under the tutelage of his father and his older brother. Here his fondness for astronomical studies was developed. He established "The Mayport Astronomical Observatory" in 1875-77. It included, at the least, a quadrant, a two-inch telescope, a meridian-circle, and a clock. Under date of 1875, September 22d, his journal records an observed altitude of *Polaris*, secured with "my quadrant." Other entries read:—

"1875, Nov. 14.—Sent to Queen last night for lenses for my telescope."

"1875, Nov. 29.—Lenses from Queen came to-night; one two-inch achromatic, and two plano-convex lenses for eye-piece."

"1875, Dec. 12.—Directed my telescope to the stars, and saw the rings of *Saturn* for the first time. . . ."

"Dec. 14.—Saw the Annular Nebula in *Lyra*. One satellite of *Saturn*. . . . All four of the stars in the Trapezium. . . ."

"1876, Jan. 26.—Got up at $\frac{1}{2}$ past 4 this morning and applied my telescope to *Jupiter* for the first time. . . ."

In 1877, at the age of twenty years, he constructed a meridian-circle instrument. The telescope of it was that of a common spy-glass, 1.6-inch aperture, and 13.45-inch focus. The axis was turned out of wood. Brass ferrules driven on the ends of the axis, and turned down, formed the pivots. The wooden circle, 13.3 inches in diameter, was graduated to 15'. KEELER's original sketch of this instrument, and his written description of it, are published elsewhere in this number of the *Publications*.

His "Record of Observations, made at the Mayport Observatory," contains beautiful colored sketches of *Jupiter*, *Saturn*, *Venus*, *Mars*, the *Orion Nebula*, of double stars, and of "Scenery on the Moon"; and in addition, data of a numerical character. These early drawings are characterized by the refined taste and skill so well known from his later professional work.

Mr. KEELER entered Johns Hopkins University late in 1877; and, following major courses in Physics and German, he was graduated with the degree of A. B. in 1881. At the end of his freshman year, he accompanied Professor HASTINGS, as a member of Professor HOLDEN's party from the Naval Observatory, to observe the total solar eclipse of July 29, 1878, at Central City, Colorado. Although his part was the modest one of making a drawing of the corona, his written report on the work is a model scientific paper, and may be read with profit by visual observers of eclipses.

In the spring of 1881, Professor LANGLEY, desiring an assistant in the Allegheny Observatory, requested the Johns Hopkins University to recommend a suitable man for the place. KEELER was named for and accepted the appointment, beginning work at Allegheny several weeks before receiving his degree. I was speaking, in June of this year (1900) with one of the physicists who had recommended KEELER for the Allegheny position, and the subject of this very appointment came up. "I told Professor LANGLEY," said he, "that one of my strongest reasons for the recommendation is that KEELER does n't claim to know everything." To the end of his life, this charming trait remained unimpaired. It is to KEELER's credit that he largely defrayed his own expenses in college by acting as assistant to some of the lecturers in the experimental courses.

Professor LANGLEY made his noted expedition to the summit of Mt. Whitney, California, in June-September, 1881, to determine the value of the "Solar Constant." Mr. KEELER accom-

panied the expedition in the capacity of assistant, and carried out his share of the programme with skill and efficiency. Returning at once to Allegheny, his work until May, 1883, was closely related to the many problems arising from the Mt. Whitney expedition.

The year 1883-4 was devoted to study and travel abroad. The months of June, July, and August, at Heidelberg, were given to the study of Light and Electricity under QUINCKE, Chemistry under BUNSEN, and Integral Calculus under FUCHS. During the winter semester, in Berlin, he heard the lectures on Physics by HELMHOLTZ and KAYSER, on Differential Equations by RUNGE, and on Quaternions by GLAN. His main investigation in the physical laboratory was on "The Absorption of Radiant Heat by Carbon Dioxide,"—a problem suggested no doubt by his Mt. Whitney experiences.

From June, 1884 to April, 1886, Mr. KEELER again served as assistant in the Allegheny Observatory, affording most efficient help to Professor LANGLEY in his classical researches on the lunar heat, and on the infra-red portion of the solar spectrum.

Early in 1886, on Professor HOLDEN's recommendation, Mr. KEELER was appointed Assistant to the Lick Trustees. He arrived at Mt. Hamilton on April 25, 1886, and immediately proceeded to establish the time service. The telegraph line to San José was perfected, the transit instruments, the clocks, and the sending and receiving apparatus at both ends of the line, were installed. The signals were sent out on and after January 1, 1887; north to Portland, east to Ogden, and south to San Diego and El Paso. In addition to the time service, he assisted the Trustees in installing the various instruments.

When the Observatory was completed, and transferred to the Regents of the University of California, on June 1, 1888, Mr. KEELER was appointed Astronomer; the original staff consisting of Astronomers HOLDEN, BURNHAM, SCHAEBERLE, KEELER and BARNARD, and Assistant Astronomer HILL.

Professor KEELER was placed in charge of the spectroscopic work of the Observatory. The large star spectroscope, constructed mainly from his designs, has no superior for visual observations. Of the many results obtained with this instrument we may mention the observations of *Saturn's* rings and *Uranus*, with reference to their atmospheres; of the bright and dark lines in the spectra of γ *Cassiopeiæ* and β *Lyræ*; of the color curve of

the 36-inch equatorial; and of the spectra of the *Orion Nebula* and thirteen planetary nebulae.

His beautiful observations on the velocities in the line of sight of these fourteen nebulae mark a distinct epoch in visual spectroscopy. His memoir on the subject took its place as a classic at once. The probable error of the final result for each nebula, based on the mean of several observations, is only ± 3.2 kilometers per second. Attention should be called to one extremely important fact established by these measures, viz: the velocities of the nebulae in their motion through space are of the same order of magnitude as the velocities of the stars.

The recognition of the fact that a great refracting telescope is also a most powerful spectroscope for special classes of objects, by virtue of the chromatic aberration of the objective, is due to Professor KEELER. Among the first objects observed with the 36-inch equatorial were the planetary nebulae and their stellar nuclei. The observers were struck with the fact that the focal length for a nebula is 0.4 inch longer than for its stellar nucleus; a discrepancy which Professor KEELER at once explained by recalling that the star's light is yellow, whereas that of the nebula is greenish-blue.

Astronomical readers will remember KEELER's splendid drawings of the planets *Saturn*, *Jupiter*, and *Mars*, made with the assistance of the 36-inch telescope, during 1888-90. His faithful and artistic drawings of *Jupiter* have no equal.

He was in charge of the very successful expedition sent by the Lick Observatory to Bartlett Springs, California, to observe the solar eclipse of January 1, 1889.

Professor KEELER resigned from the Lick Observatory staff on June 1, 1891, to succeed Professor LANGLEY as Director of the Allegheny Observatory and Professor of Astrophysics in the Western University of Pennsylvania. The Allegheny Observatory has perhaps the poorest location of any observatory in this country for spectroscopic work. But in spite of this disadvantage, KEELER's investigations continued and promoted the splendid reputation established for the observatory by his predecessor. He comprehended the possibilities and limitations of his situation and his means, and adapted himself to them. His spectroscopic researches were largely confined to the orange, yellow, and green regions of the spectrum, since these would be less strongly affected by the smoky sky, for which that vicinity is famous.

The Allegheny spectroscope, designed and constructed soon after his acceptance of the position, contained several valuable improvements. The use of three simple prisms in its dispersive train was a departure which has been followed with great advantage in many later instruments. With this instrument he made an extensive investigation of the *Orion Nebula* and the stars immersed in it, establishing the fact that the nebula and the stars are closely related in physical condition.* His beautiful observations of *Saturn's* rings, proving that they are a cluster of meteorites — myriads of little moons — have never been surpassed in interest in the entire astronomical field. These observations are so well known to every one interested in astronomy that a single sentence suffices. He proved spectrographically, using the Doppler-Fizeau principle, that every point in the ring system is moving with the velocity which a moon would have if situated at that distance from the planet. Professor KEELER'S main piece of work at the Allegheny Observatory, on the spectra of the third (Secchi) type stars remains unpublished, but the measures and reductions are left in an advanced stage.

The Regents of the University of California appointed Professor KEELER to the position of Director of the Lick Observatory on March 8, 1898. The ties which bound him and his family to Allegheny were difficult to sever; but the greater opportunities offered by the instruments and the atmospheric conditions at Mt. Hamilton decided him in favor of accepting the appointment. He entered upon his new duties on June 1, 1898.

Without making any rearrangement of the work of the staff, but affording them every possible encouragement to continue along the same lines, Professor KEELER arranged to devote his own observing-time to the Crossley reflector. He recognized that the instrument was not in condition to produce satisfactory results. He made one change after another, overcoming one difficulty after another, until, on November 14th, he secured an excellent negative of the *Pleiades*, and on November 16th, a superb negative of the *Orion Nebula*. The enormous power of the reflector in nebular photography was established, and he entered upon the programme of photographing all the brighter nebulae in HERSCHEL'S catalogue. More than half of the subjects on the programme have been completed. The Observatory

* Simultaneous observations of the same object made at another observatory led to the same conclusion.

possesses a set of negatives of the principal nebulae which is priceless and unequalled. These photographs have already led to many discoveries of prime importance; and they furnish a vast amount of material for future investigations of questions bearing especially upon the early stages of sidereal evolution. The photographs record, incidentally, great numbers of new nebulae; as many as thirty-one on a single plate covering less than one square degree of the sky. A conservative estimate places the number within reach of the Crossley reflector at 120,000, of which only ten or fifteen thousand have thus far been discovered.

It has previously been supposed that the great majority of nebulae are irregular and without form, and that only a few are spirals. Professor KEELER's photographs have recorded more spiral nebulae than irregular ones. This discovery bears profoundly on the theories of the cosmogony, and must be considered as of the first order.

It is time to refer to Professor KEELER's work as Director. I but faintly reflect the views of every member of the staff, and indeed of all who have been interested in the work of this Observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work, in a splendidly scientific manner; and he saw to it that every one had all possible opportunities to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results. No one's plans were torn up by the roots to see if they were growing. The peace of mind of the investigator, so absolutely essential for complete success, was full and undisturbed. Withal, Professor KEELER's administration was so kind and so gentle, and yet so effective, that the reins of government were seldom seen and never felt.

The elements of his successes are simple, and plainly in view. His openness and honesty of character, his readiness and quickness to see the other man's point of view, his strong appreciation of the humorous, as well as the serious, and above all his abounding good sense, — these traits made his companionship delightful and charming. Scientifically, Professor KEELER never groped aimlessly in the dark. He would not attack a problem until he had as fully as possible comprehended its nature, and the requirements for success. With the plan of attack completely considered, and the instruments of attack at hand, the execution of his

plans involved little loss of time. The Crossley reflector affords a case in point. Assisted by a Fellow in Astronomy and by the instrument-maker, he devoted five months to preparing the reflector for turning out the magnificent results which *at once* followed.

Professor KEELER's published papers have a finish and a ripeness which are rarely seen. His love of the beautiful and his artistic skill are evident in all his work.

To speak of the people who had afforded him encouragement at different times in his life, was one of his pleasures. His father's friend, Mr. CHAS. H. ROCKWELL, of Tarrytown, was constant in urging the development of so promising a career. He did not forget Professor HASTINGS' continual kindness and interest during his college days. He frequently spoke of the great value of Mr. WILLIAM THAW's interest and encouragement, both to himself and to the Allegheny Observatory; an interest which was continued after Mr. THAW's death by other members of Mr. THAW's family.

The honorary degree of Sc. D. was conferred upon Professor KEELER in 1893 by the University of California. He received the Rumford medal from the American Academy of Arts and Sciences in 1898, and the Henry Draper medal from the National Academy of Sciences in 1899. He was a member of the National Academy of Sciences; an Associate of the American Academy of Arts and Sciences; a Fellow and Foreign Associate of the Royal Astronomical Society; a Fellow of the American Association for the Advancement of Science; a member and officer of the Astronomical and Astrophysical Society of America; an honorary member of the Toronto Astronomical and Physical Society; the President of the Astronomical Society of the Pacific; a member of the Washington Academy of Sciences, and various other organizations.

It appears that Professor KEELER had long been a sufferer from a mild form of heart weakness; to run even fifteen steps caused him great physical distress. It is feared that on Mt. Hamilton he worked beyond his strength. His weakness seemed to develop rapidly this summer. He went away from the Observatory on July 30th, in the best of spirits, and with no anxiety, to secure medical treatment, and to spend a brief vacation in the northern part of the State. Increasing difficulty in breathing led him to seek skilled treatment in San Francisco, on August 10th.

His dangerous condition was recognized on August 11th, and on the 12th a stroke of apoplexy proved fatal.

When the dangerous weakness of his heart was discovered by the physicians, Professor KEELER's main regret was that he would have to leave Mt. Hamilton and its opportunities, in order to live at a lower altitude. It is known that he had planned his work with the Crossley reflector far into the future. A small spectrograph which he was most anxious to employ on certain interesting spectra was completed on the day of his leaving the Observatory.

The absence of one so old in experience and so ripe in judgment will be seriously felt throughout his profession.

Professor KEELER married Miss CORA S. MATTHEWS at Oakley Plantation, Louisiana, on June 16, 1891. Of her great sorrow, and of the grievous loss to the two children, it would be futile to speak.

W. W. CAMPBELL.

THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.*

By JAMES E. KEELER.

The Crossley reflector, at present the largest instrument of its class in America, was made in 1879 by Dr. A. A. COMMON, of London, in order to carry out, and test by practical observation, certain ideas of his respecting the design of large reflecting telescopes. For the construction of the instrument embodying these ideas, and for some fine astronomical photographs obtained with it, Dr. COMMON was awarded the gold medal of the Royal Astronomical Society in 1884.

In 1885, Dr. COMMON, wishing to make a larger telescope on a somewhat similar plan, sold the instrument to EDWARD CROSSLEY, Esq., F. R. A. S., of Halifax, England. Mr. CROSSLEY provided the telescope with a dome of the usual form, in place of the sliding roof used by its former owner, and made observations with it for some years; but the climate of Halifax not being

* Reprinted from the *Astrophysical Journal* for June, 1900.

suitable for the best use of such a telescope, he consented, at the request of Dr. HOLDEN, then Director of the Lick Observatory, to present it to this institution. The funds for transporting the telescope and dome to California, and setting them up on Mt. Hamilton, were subscribed by friends of the Lick Observatory, for the most part citizens of California. The work was completed, and the telescope housed in a suitable observatory building, in 1895.*

On taking charge of the Lick Observatory in 1898, I decided to devote my own observing time to the Crossley reflector, although the whole of my previous experience had been with refracting telescopes. I was more particularly desirous of testing the reflector with my own hands, because such preliminary trials of it as had been made had given rise to somewhat conflicting opinions as to its merits.† The result of my experience is given in the following article, which is written chiefly with reference to American readers. If I have taken occasion to point out what I regard as defects in the design or construction of the instrument, I have done so, not from any desire to look a gift horse in the mouth, but in the interest of future improvement, and to make intelligible the circumstances under which the work of the reflector is now being done and will be done hereafter. The most important improvements which have suggested themselves have indeed already been made by Dr. COMMON himself, in constructing his five-foot telescope. The three-foot reflector is, in spite of numerous idiosyncrasies which make its management very different from the comparatively simple manipulation of a refractor, by far the most effective instrument in the Observatory for certain classes of astronomical work. Certainly no one has more reason than I to appreciate the great value of Mr. CROSSLEY's generous gift.

The Crossley dome is about 350 yards from the main Observatory, at the end of a long rocky spur which extends from the Observatory summit toward the south, and on which are two of the houses occupied by members of the Observatory staff. It is below the level of the lowest reservoir, "Huyghens," which

* For a more complete history of this part of the subject, see Dr. Holden's articles in *Pub. Ast. Soc. Pacific*, No. 7, 197 *et seq.*, 1895.

† The difficulties here referred to, about which a good deal has been written, seem to have had their origin in the fact that it was impossible, at the time of the preliminary trials, to provide the observer with an assistant, while the Crossley reflector is practically unmanageable by a single person.

receives the discharge from the hydraulic machinery of the 36-inch refractor, and therefore the water-engine furnished by Mr. CROSSLEY for turning the dome cannot be used, unless a new water system — overflow reservoir, pump and windmill — is provided. In this respect a better site would have been a point on the south slope of "Kepler," — the middle peak of Mt. Hamilton — just above the Huyghens reservoir. No addition to the present water system would then have been needed. The slope of the mountain at this place might cut off the view of the north horizon, but since the telescope cannot be turned below the pole, this would be a matter of no consequence. Water-power for the dome is not, however, really necessary.

The cylindrical walls of the dome, $36\frac{1}{4}$ feet inside diameter, are double, and provided with ventilators. Opening into the dome, on the left of the entrance, are three small rooms, one of which has been fitted up as a photographic dark room, and another, containing a sidereal clock and a telephone which communicates with the main Observatory, as a study, while the third is used for tools and storage. There is also a small room for the water-engine, in case it should be used. The dome is at present supplied with water from only the middle reservoir, Kepler, which is reserved for domestic purposes and is not allowed to pass through the machinery.

The dome itself, 38 feet 9 inches in diameter, is made of sheet-iron plates riveted to iron girders. It also carries the wooden gallery, ladders, and observing platform, which are suspended from it by iron rods. The apparatus for turning the dome consists of a cast-iron circular rack bolted to the lower side of the sole-plate, and a set of gears terminating in a sprocket-wheel, from which hangs an endless rope. As the dome does not turn easily, it has been necessary to multiply the gearing of the mechanism so that one arm's-length pull on the rope moves the dome only about one inch. In some positions of the telescope the dome cannot be moved more than six or eight inches at a time without danger of striking the tube, and this slowness of motion is then not disadvantageous. It is only when the dome has to be moved through a considerable angle, as in turning to a fresh object, or in photographing some object which passes nearly through the zenith, that the need for a mechanical means of rotation is felt.

The observing slit, 6 feet wide, extends considerably beyond



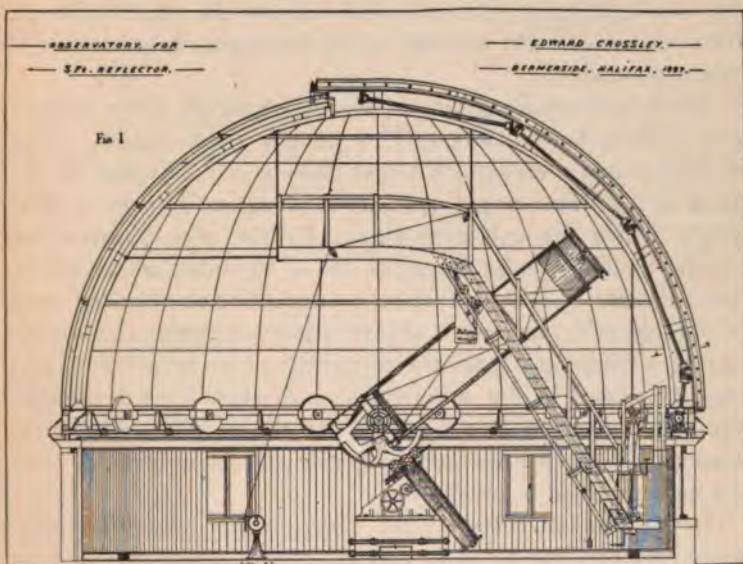
DOME OF THE CROSSLEY REFLECTOR.

1

2

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the zenith. It is closed by a double shutter, which is operated by an endless rope. The upper part, within the dome, is also closed by a hood, or shield, which serves to protect the telescope from any water that may find its way through the shutter, and which is rolled back to the north when observations are made near the zenith. I have recently fitted the lower half of the slit with a wind-screen, which has proved to be a most useful addition. It is made of tarpaulin, attached to slats which



THE CROSSLEY REFLECTOR.

slide between the two main girders, and is raised or lowered by halyards, which belay to cleats on the north rail of the gallery. A more detailed description of the dome has been given in an article by Mr. CROSSLEY,* from which the reduced figure in Fig. 1† has been taken.

The mounting of the three-foot reflector has been very completely described and illustrated by Dr. COMMON,‡ so that only a very general description need be given here. The most important feature of the mounting is that the telescope-tube, instead of being on one side of the polar axis, as in the usual construction, is central, so that the axis of the mirror and the polar

* *Mon. Not. R. A. S.*, No. 48, 386.

† Kindly lent by the Astronomical Society of the Pacific.

‡ *Mem. R. A. S.*, No. 46, 173.

axis are in the same line when the telescope is directed to the pole. The declination axis is short, and is supported by a massive goose-neck bolted to the upper end of the polar axis. The mirror is placed just *above* the declination axis. Its weight, and the weight of the whole tube and eye-end, are counterpoised by slabs of lead, placed in two iron boxes, between which the goose-neck of the polar axis passes. The great advantage of this arrangement, and the controlling principle of the design, is that the telescope is perfectly free to pass the meridian at all zenith distances. No reversal of the instrument is needed, or is indeed possible.

For long-exposure photography, the advantage above referred to is obvious, but it is attended by certain disadvantages. One of these is that a very much larger dome is required than for the usual form of mounting. Another is the great amount of dead weight which the axis must carry; for the mirror, instead of helping to counterpoise the upper end of the tube, must itself be counterpoised. When anything is attached to the eye-end (and in astrophysical work one is always attaching things to the eye-end of a telescope), from ten to twenty times as much weight must be placed in the counterpoise boxes below the declination axis. Where room is to be found for the weights required to counterpoise the Bruce spectrograph, is a problem which I have not yet succeeded in solving.

In his five-foot reflector, Dr. COMMON has caused the telescope tube to swing between two large ears, which project from the upper end of the boiler-like polar axis, the pivots constituting the declination axis being near, but above, the lower end of the tube. The mirror therefore helps to counterpoise the upper end of the tube. This I regard as a distinct improvement. The danger of large masses of metal near the mirror injuring the definition is, in my opinion, imaginary; at least there is no such danger on Mt. Hamilton, where the temperature variations are unusually small. Experience with the Crossley reflector, as well as with the other instruments of the Lick Observatory, shows that the definition depends almost entirely on external conditions.

My first trials of the reflector, as first mounted at the Lick Observatory, showed that the center of motion was inconveniently high. Among other difficulties arising from this circumstance, the spectroscope projected beyond the top of the dome, so that it had to be removed before the shutter could be closed. In July,



THE CROSSLEY REFLECTOR.

1898, the pier was therefore cut down two feet. This brought the eye-end down nearly to the level of the gallery rail, where it was at a convenient height for the observer when sitting on a camp-stool, and it made all parts of the mounting more accessible. Toward the north and south, the range of the telescope, being limited in these directions by the construction of the mounting, was not affected by the change, but the telescope cannot now be used at such low altitudes as formerly, near the east and west points of the horizon. The only occasion likely to call for the use of the reflector in these positions is the appearance of a large comet near the Sun, and after some consideration, I decided to sacrifice these chances for the sake of increasing the general usefulness of the instrument. Except in rare cases, all observations are made within three hours of the meridian.

To adapt the mounting to the latitude of Mt. Hamilton, a wedge-shaped casting, shown in the accompanying plate, had been provided, but through some error, arising probably from the fact that the telescope had been used in two different latitudes in England, the angle of the casting was too great. When the pier was cut down, its upper surface was therefore sloped toward the south in order to compensate the error in the casting. The plate shows the instrument very nearly as it is at the present time.

The polar axis of the Crossley reflector is a long, hollow cylinder, separated by a space of about one eighth of an inch from its concentric casing. The idea was to fill this space with mercury, and float the greater part of the thrust of the axis, the function of a small steel pin at the lower end being merely to steady the axis. But this mercury flotation, as applied to the Crossley telescope, is a delusion, as I think Mr. CROSSLEY had already found. The mercury, it is true, relieves the thrust to some extent, but it greatly increases the already enormous side pressure on the steel pin at the bottom, thus creating a much greater evil than the one it is intended to remedy. The workmen who set up the mounting inform me that the small bearing at the lower end of the polar axis is badly worn, as I should expect it to be. Instead of putting mercury into the space intended for it, I have therefore poured in a pint or so of oil, to keep the lower bearing lubricated. For the reasons indicated above, the force required to move the telescope in right ascension is perhaps five times greater than it should be. The lower

end of the polar axis ought to be fitted with ball bearings to take the thrust, and with a pair of friction wheels on top; but it would be difficult to make these changes now. It should be observed that the disadvantages of the mercury flotation are considerably greater at Mt. Hamilton than at the latitude for which the telescope was designed.

As already stated above, the range of the telescope is limited on the south by the construction of the mounting. The greatest southern declination which can be observed is 25° . In England this would doubtless mark the limit set by atmospheric conditions, but at Mt. Hamilton it would be easy to photograph objects 15° farther south, if the telescope could be pointed to them.

The original driving-clock having proved to be inefficient, at least without an electric control, a new and powerful driving-clock was made by the Observatory instrument-maker, from designs by Professor HUSSEY. In its general plan it is like that of the 36-inch refractor. The winding apparatus contained in the large casting of the original mounting has no maintaining power, and cannot easily be fitted with one. The clock could in no case be wound during a photographic exposure, on account of the tremors attending the operation, but it would be somewhat more convenient to have the stars remain on the plate during the winding. With a little practice, however, one can wind the clock without actually stopping it, though the object must afterwards be brought back to its place by means of the slow motion in right ascension.

Two finders have recently been fitted to the Crossley reflector. One has an object-glass of four inches aperture and eight feet six inches focal length, with a field of about $1^{\circ} 2'$, which is very nearly the photographic field of the main telescope. Its standards are bolted to one of the corner tubes of the reflector, as shown in the plate (page 151). The other finder has a three-inch objective and a large field. It had not been mounted when the photograph for the plate was made.

When a telescope is used for photographing objects near the pole, with long exposures, the polar axis must be quite accurately adjusted, for otherwise the centers of motion of the stars and of the telescope will not agree, and the star images will be distorted. It is true that with a double-slide plate-holder, like the one used with the Crossley reflector, one star — namely the guiding star — is forced to remain in a fixed position with respect to the plate;

but the differential motion of the other stars causes them to describe short arcs, or trails, around this star as a center. A considerable part of the spring of 1899 was spent in efforts to perfect the adjustment of the polar axis, an operation which, on account of the peculiar form of the mounting, offers unusual difficulties.

In the first plan which was tried, the reflector was used as a transit instrument. The inclination of the declination axis was determined with a hanging level which had been provided by Mr. CROSSLEY, the hour circle and polar axis being very firmly clamped. The clock correction being known from the records kept at the Observatory, the collimation and azimuth constants were found by the usual formulæ. This method failed to give satisfactory results, and it was found later that the declination and polar axis were not exactly at right angles.

There is only one part of the sky on which the telescope can be reversed; namely, the pole. A method which promised well, and on which some time was spent, consists in photographing the pole (the declination axis being horizontal) by allowing the stars near it to trail for ten or fifteen minutes, then turning the polar axis 180° and photographing the pole again on the same plate. Half the distance between the images gives the error of the polar axis, which, if the plate is properly oriented, is easily resolved into horizontal and vertical components; while the distance of each image from the center of the plate is this error increased or diminished by twice the deviation of the telescope axis. In this case the vertical component depends upon the reading of the declination circle, and the horizontal component gives the error of collimation. This method failed, however, to give consistent results, mainly on account of instability of the mirror, and was abandoned.

The use of the large mirror for purposes of adjustment was finally given up, and the axis was adjusted by observations of *Polaris* with the long finder, in the usual manner. In order to reach the star at lower culmination the finder tube had to be thrown out of parallelism with the main telescope.

The base-plate having no definite center of rotation in azimuth, and the wedges and crowbars used for moving it being uncertain in their action, a watch telescope, provided with a micrometer eye-piece, was firmly secured to the mounting throughout these operations, in such manner that a mark on the southern horizon

could be observed through one of the windows of the dome. The errors of the polar axis were finally reduced to within the limits of error of observation.

The movable hour-circle and driving-wheel of the Crossley reflector has two sets of graduations. The driving-screw having been thrown out of gear, the circle is turned until the outer vernier indicates the sidereal time, whereupon the driving-screw is thrown into gear again. The inner vernier is then set to the right ascension of the object which it is desired to observe. As an inconsistency of minor importance in the design of the mounting, I may note that the slow motion in right ascension changes the reading of the outer vernier instead of that of the inner one. In practice, however, no inconvenience is caused by this construction.

In the early experiments and photographic work with the Crossley telescope, irregularities in driving were a source of great annoyance. Dr. ROBERTS, in laying down the conditions which should be fulfilled by a good photographic telescope, says that a star should remain bisected by a thread in the eye-piece for two minutes at a time. The Crossley telescope was so far from fulfilling this condition that a star would not keep its place for two consecutive seconds; and the greatest alertness on the part of the observer did not suffice to insure round star-images on a photographic plate. It was obvious that the fault did not lie with the driving-clock; in fact, many of the sudden jumps in right ascension, if explained in this way, would have required the clock to run backward; nevertheless the clock was tested by causing its revolutions to be recorded on a chronograph at the main Observatory, together with the beats of one of the standard clocks. For this purpose a break-circuit attachment was made by Mr. PALMER. The errors of the clock were in this way found to be quite small.

The principal source of the irregularities was found in the concealed upper differential wheel of the Grubb slow motion. This wheel turned with uncertain friction, sometimes rotating on its axis, and sometimes remaining at rest. After it was checked the driving was much better, and was still further improved by repairing some defective parts of the train. Small irregularities still remain. They seem to be partly due to inaccuracies in the cutting of the gears, or of the teeth of the large driving-wheel, and partly to the springing of the various parts, due to the very

considerable friction of the polar axis in its bearings. The remaining irregularities are so small, however, that they are easily corrected by the screws of the sliding plate-holder, and with reasonable attention on the part of the observer, round star-images are obtained with exposures of four hours' duration.

The large mirror, the most important part of the telescope, has an aperture of three feet, and a focal length of 17 feet 6.1 inches. It was made by Mr. CALVER. Its figure is excellent. On cutting off the cone of rays from a star, by a knife-edge at the focus, according to the method of FOUCAULT, the illumination of the mirror is very uniform, while the star-disks as seen in an ordinary eye-piece are small and almost perfectly round. They are not, I think, quite so good as the images seen with a large refractor; still, they are very good, indeed, as the following observations of double stars, made recently for this purpose, will show.

Several close double stars were examined on the night of April 17, 1900, with a power of 620. The seeing was four on a scale of five. The magnitudes and distances of the components, as given in the table, are from recent observations by Professor HUSSEY with the 36-inch refractor.

Star	Mag.	d.	Result of Obs.
OΣ 208 (<i>φ</i> <i>Urs. Maj.</i>)	5.0, 5.5	0".35	Not resolved; too bright.
OΣ 249, AB	7.2, 8.0	0 .54	Easily resolved.
OΣ 250	7.7, 8.0	0 .44	Resolved.
OΣ 267	8.0, 8.2	0 .30	Just resolved at best moments.

Although the theoretical limit of resolution for a three-foot aperture is not reached in these observations, I do not think the mirror can do any better.

The small mirror, or flat, at the upper end of the tube, is circular, the diameter being nine inches. Its projection on the plane of the photographic plate is therefore elliptical; but the projection of the mirror and its cell on the plane of the great mirror is very nearly circular.

The small mirror, acting as a central stop, has the effect of diminishing the size of the central disk of the diffraction pattern, at the expense of an increase in the brightness of the system of rings. To this effect may be due, in part, the inferiority of the reflector for resolving bright doubles, as compared with a refractor of the same aperture. For photographic purposes, it is evident that the mirror is practically perfect.

The upper end of the tube can be rotated, carrying with it the flat and the eye-end. Whenever the position is changed, the mirrors have to be re-collimated. In practice it is seldom necessary to touch the adjusting screws of the mirrors themselves. The adjustment is effected by means of clamping and butting screws on the eye-end, and a change of the line of collimation with respect to the finders and the circles is avoided. The operation is generally referred to, however, as an adjustment of the mirrors.

For adjusting the mirrors there are two collimators. One of these is of the form devised by Mr. CROSSLEY.* It is very convenient in use, and is sufficiently accurate for the adjustment of the eye-end when the telescope is used for photographic purposes, inasmuch as the exact place where the axis of the large mirror cuts the photographic plate is not then a matter of great importance, so long as it is near the center. Moreover, as stated farther below, the direction of the axis changes during a long exposure. The other collimator is of a form originally due, I think, to Dr. JOHNSTONE STONEY. It consists of a small telescope, which fits the draw-tube at the eye-end. In the focus of the eye-piece are, instead of cross-wires, two adjustable terminals, between which an electric spark can be passed, generated by a small induction machine, like a replenisher, held in the observer's hand. The terminals are at such a distance inside the principal focus of the objective, that the light from the spark, after reflection from the flat, appears to proceed from the center of curvature of the large mirror. The rays are therefore reflected back normally, and form an image of the spark which, when the mirrors are in perfect adjustment, coincides with the spark itself. The precision of this method is very great. It is in fact out of proportion to the degree of refinement attained in other adjustments of the reflector, for a slight pressure of the hand on the draw-tube, or movement of the telescope to a different altitude, instantly destroys the perfection of the adjustment. I have provided these collimators with an adapter which fits the photographic apparatus, so that one can adjust the mirrors without having to remove this apparatus and substitute for it the ordinary eye-end carrying the eye-pieces.

For visual observation the Crossley telescope is provided with seven eye-pieces, with powers ranging from 620 downward.

* *Mon. Not. R. A. S.*, No. 48, 280, 1888

The lowest power is only 60, and consequently utilizes only twelve inches of the mirror, nine of which are covered by the central flat. It is therefore of little value, except for finding purposes. The next lowest power utilizes twenty-eight inches of the mirror. The other eye-pieces call for no remark.

But, while the Crossley reflector would doubtless be serviceable for various kinds of visual observations, its photographic applications are regarded as having the most importance, and have been chiefly considered in deciding upon the different changes and improvements which have been made.

The interior of the dome is lighted at night by a large lamp, which is inclosed in a suitable box or lantern, fitted with panes of red glass, and mounted on a portable stand. In order to diffuse the light in the lower part of the dome, where most of the assistant's work is done, the walls are painted bright red; while to prevent reflected light from reaching the photographic plate, the inner surface of the dome itself, the mounting, and the ladders and gallery are painted dead black. The observer is therefore in comparative darkness, and not the slightest fogging of the plate, from the red light below, is produced during a four-hours' exposure. On the few occasions when orthochromatic plates are used, the lamp need not be lighted.

Experiments have shown that the fogging of the photographic plate, during a long exposure, is entirely due to diffuse light from the sky, and is therefore unavoidable. For this reason the cloth curtains which lace to the corners of the telescope-tube, inclosing it and shutting out light from the lower part of the dome, have not been used, since their only effect would be to catch the wind and cause vibrations of the telescope. They would probably have little effect on the definition, and at any rate could not be expected to improve it.

For photographing stars and nebulae the Crossley reflector is provided with a double-slide plate-holder, of the form invented by Dr. COMMON.* This apparatus, which had suffered considerably in transportation, and from general wear and tear, was thoroughly overhauled by the Observatory instrument-maker. The plates were straightened and the slides refitted. A spring was introduced to oppose the right-ascension screw and take up the lost

* *Mon. Not. R. A. S.*, No. 49, 297. The construction here described is not followed exactly in the Crossley apparatus. The guiding eye-piece slides freely when not held by a clamp. Pin-holes for preventing fogging are unnecessary when red light is used.

motion — the most annoying defect that such a piece of apparatus can have — and various other improvements were made, as the necessity for them became apparent. They are described in detail farther below.

The present appearance of the eye-end is shown in the plate facing p. 159. The plate-holder is there shown, however, on one side of the tube, and its longer side is parallel to the axis of the telescope. This is not a good position for the eye-end, except for short exposures. In practice, the eye-end is always placed on the north or south side of the tube, according as the object photographed is north or south of the zenith. The right-ascension slide is then always at right angles to the telescope axis, and the eye-end cannot get into an inaccessible position during a long exposure.

As the original wooden plate-holders were warped, and could not be depended upon to remain in the same position for several hours at a time, they were replaced by new ones of metal, and clamping-screws were added, to hold them firmly in place. The heads of these screws are shown in the plate, between the springs which press the plate-holder against its bed.

To illuminate the cross-wires of the guiding eye-piece, a small electric lamp is used, the current for which is brought down from the storage battery at the main Observatory. The coarse wires have been replaced by spider's webs,* and reflectors have been introduced, to illuminate the declination thread. A collimating lens, placed at its principal focal distance from the incandescent filament of the lamp, makes the illumination of the wires nearly independent of their position on the slide, and a piece of red glass, close to the lens, effectually removes all danger of fogging the plate. The light is varied to suit the requirements of observation by rotating the reflector which throws the light in the direction of the eye-piece.

In long exposures it is important for the observer to know at any moment the position of the plate with reference to its central or zero position. For this purpose scales with indexes are attached to both slides; but as they cannot be seen in the dark, and, even if illuminated with red light, could not be read without removing the eye from the guiding eye-piece, I have added two

*It so happens that the tension of the vertical thread is such that it begins to slacken when the temperature falls to within about 2° of the dew point. The thread thus forms an excellent hygrometer, which is constantly under the eye of the observer. When the thread becomes slack, it is time to cover the mirrors.



short pins, one of which is attached to the lower side of the right-ascension slide, and the other to its guide, so that the points coincide when the scale reads zero. These pins can be felt by the fingers, and with a little practice the observer can tell very closely how far the plate is from its central position. It would not be a very difficult matter to improve on this contrivance, say by placing an illuminated scale, capable of independent adjustment, in the field of the eye-piece, but the pins answer every purpose. The declination slide is changed so little that no means for indicating its position are necessary.

In this apparatus, as originally constructed, the cross-wires of the guiding eye-piece were exactly in the plane of the photographic plate. The earlier observations made with the Crossley reflector on Mt. Hamilton showed that this is not the best position of the cross-wires. The image of a star in the guiding eye-piece, which, when in the middle of its slide, is nearly three inches from the axis of the mirror, is not round, and its shape varies as the eye-piece is pushed in or drawn out. In the plane of the photographic plate (assumed to be accurately in focus), it is a crescent, with the convex side directed toward the center of the plate. This form of image is not suitable for accurate guiding. Outside this position the image changes to an arrow-head, the point of which is directed toward the axis, and this image can be very accurately bisected by the right-ascension thread. As the construction of the apparatus did not allow the plane of the cross-wires to be changed, the wooden bed of the plate-holder was cut down, so as to bring the wires and the plate into the proper relative positions.

After some further experience with the instrument, still another change was made in this adjustment. It was found that the focus often changed very perceptibly during a long exposure, and while the arrow-head image above described was suitable for guiding purposes, its form was not greatly affected by changes of focus. Between the crescent and the arrow-head images there is a transition form, in which two well-defined caustic curves in the aberration pattern intersect at an acute angle. The intersection of these caustics offers an excellent mark for the cross-wires, and is at the same time very sensitive to changes of focus, which cause it to travel up or down in the general pattern. The bed of the plate-holder was therefore raised, by facing it with a brass plate of the proper thickness.

Why the focus of the telescope should change during a long exposure is not quite clear. The change is much too great to be accounted for by expansion and contraction of the rods forming the tube, following the changes of temperature, while a simple geometrical construction shows that a drooping of the upper end of the tube, increasing the distance of the plate from the (unreflected) axis of the mirror, cannot displace the focus in a direction normal to the plate, if it is assumed that the field is flat. The observed effect is probably due to the fact that the focal surface is not flat, but curved. During a long exposure, the observer keeps the guiding-star, and therefore, very approximately, all other stars, in the same positions relatively to the plate; but he has no control over the position of the axis of the mirror, which, by changes of flexure, wanders irregularly over the field. The position of maximum curvature, therefore, also varies, and with it the focus of the guiding-star relatively to the cross-wires, where the focal surface is considerably inclined to the field of view. It is certain that the focus does change considerably, whatever the cause may be, and that the best photographic star-images are obtained by keeping the focus of the guiding-star unchanged during the exposures. This is done by turning the focusing-screw of the eye-end.

In making the photographs of nebulae for which the Crossley telescope is at present regularly employed, it was at first our practice to adjust the driving-clock as accurately as possible to a sidereal rate, and then, when the star had drifted too far from its original position, on account of changes of rate or of flexure, to bring it back by the right-ascension slow motion, the observer either closing the slide of the plate-holder or following the motion of the star as best he could with the right-ascension screw. Lately a more satisfactory method, suggested by Mr. PALMER, has been employed. The slow motion in right ascension is of Grubb's form,* and the telescope has two slightly different rates, according to whether the loose wheel is stopped or allowed to turn freely. The driving-clock is adjusted so that one of these rates is too fast, the other too slow. At the beginning of an exposure the wheel is, say, unclamped, and the guiding-star begins to drift very slowly toward the left, the observer following it with the screw of the plate-holder. When it has drifted far enough, as indicated by the pins mentioned farther above, the

* *Mon. Not. R. A. S.*, No. 48, 352.

wheel is clamped. The star then reverses its motion and begins to drift toward the right; and so on throughout the exposure. The advantages of this method over the one previously employed are, that the star never has to be moved by the slow motion of the telescope, and that its general drift is in a known direction, so that its movements can be anticipated by the observer. In this way photographs are obtained, with four hours' exposure, on which the smallest star disks are almost perfectly round near the center of the plate, and from 2" to 3" in diameter.

The star-images are practically round over a field at least 1 inch or 16' in diameter. Farther from the center they become parabolic, but they are quite good over the entire plate, $3\frac{1}{4}$ by $4\frac{1}{4}$ inches.

From these statements it will be seen that small irregularities in driving no longer present any difficulties. But certain irregular motions of the image still take place occasionally, and so far it has not been possible entirely to prevent their occurrence.

It was found that the declination clamp (the long slow-motion handle attached to which is shown in the plate facing p. 151) was not sufficiently powerful to hold the telescope firmly during a long exposure. A screw-clamp was therefore added, which forces the toothed declination sector strongly against an iron block just behind it, thus restoring, I think, the original arrangement of the declination clamp as designed by Dr. COMMON. This clamp holds the tube very firmly.

The irregularities to which I have referred consist in sudden and unexpected jumps of the image, which always occur some time after the telescope has passed the meridian. These jumps are sometimes quite large — as much as one sixteenth of an inch or 1'. They are due to two causes; flexure of the tube, and sliding of the mirror on its bed. When the jump is due to sudden changes of flexure, the image moves very quickly, and vibrates before it comes to rest in its new position, and at the same time there is often heard a slight ringing sound from the tension rods of the tube. There seems to be no remedy for the sudden motions of this class. The tension rods are set up as tightly as possible without endangering the threads at their ends or buckling the large corner tubes. A round telescope-tube made of spirally-wound steel ribbon riveted at the crossings, would probably be better than the square tube now in use.

Jumps due to shifting of the mirror are characterized by a

gentle, gliding motion. They can be remedied, in part, at least, by tightening the copper bands which pass around the circumference of the mirror within its cell. This will be done the next time the mirror is resilvered.

All that the observer can do when a jump occurs is to bring back the image as quickly as possible to the intersection of the cross-wires. If all the stars on the plate are faint, no effect will be produced on the photograph; but stars of the eighth magnitude or brighter will leave short trails. The nebula, if there is one on the plate, will, of course, be unaffected.

Before beginning an exposure the focus is adjusted by means of a high-power positive eye-piece. An old negative, from which the film has been partially scraped, is placed in one of the plate-holders, and the film is brought into the common focus of the eye-piece and the great mirror. The appearance of the guiding-star, which varies somewhat with the position of the guiding eye-piece on its slide, is then carefully noted, and is kept constant during the exposure by turning, when necessary, the focusing screw of the eye-end. For preliminary adjustments a ground-glass screen is often convenient. On it all the *DM* stars, and even considerably fainter ones, as well as the nebulae of HERSCHEL's Class I, are easily visible without a lens.

Plates are backed, not more than a day or two before use, with CARBUTT'S "Columbian backing," which is an excellent preparation for this purpose. During the exposure the observer and assistant exchange places every half hour, thereby greatly relieving the tediousness of the work, though two exposures of four hours each, in one night, have proved to be too fatiguing for general practice. At the end of the first two hours it is necessary to close the slide and wind the clock.

The brightness of the guiding-star is a matter of some importance. If the star is too bright, its glare is annoying; if it is too faint, the effort to see it strains the eye, and changes of focus are not easily recognized. A star of the ninth magnitude is about right. In most cases a suitable star can be found without difficulty.

In such an apparatus as that described above, the amount by which the plate may be allowed to depart from its zero position is subject to a limitation which has not, I think, been pointed out, although it is sufficiently obvious when one's attention has been called to it. It depends upon the fact that the plate necessarily moves as a whole, in a straight line which is tangent to a great

circle of the sphere, while the stars move on small circles around the pole. The compensation for drift, when the plate is moved, is therefore exact at the equator only.

Let the guiding-star have the declination δ_1 and let a star on the upper edge of the plate (which, when the telescope is north of the zenith, and the eye-end is on the north side of the telescope, will be the southern edge) have the declination δ_2 . Then if the guiding-star is allowed to drift from its zero position through the distance d , the other star will drift through the distance $d \frac{\cos \delta_2}{\cos \delta_1}$. If the guiding-star is followed by turning the right-ascension screw, the upper edge of the plate, as well as the guiding eye-piece, will be moved through the distance d . Hence, there will be produced an elongation of the upper star, represented by

$$e = d \left(\frac{\cos \delta_2}{\cos \delta_1} - 1 \right)$$

$$\text{from which } d = \frac{e \cos \delta_1}{\cos \delta_2 - \cos \delta_1}.$$

Now, in the Crossley reflector, the upper edge of the plate and the guiding eyepiece are just about $3\frac{3}{4}$ inches, or 1° , apart. If e is given, the above formula serves to determine the maximum range of the slide for different positions of the telescope.

It has been stated farther above that the smallest star disks, on a good photograph, are sometimes not more than $2''$ in diameter, or in a linear measure, about $\frac{1}{10}^{\text{mm}}$. An elongation of this amount is therefore perceptible. There are many nebulae in high northern declinations, and there are several particularly fine ones in about $+70^\circ$. If, therefore, we take $\delta_2 = 70^\circ$, $\delta_1 = 71^\circ$, $e = 0.05$, and substitute these values, we find $d = 1.0^{\text{mm}}$, which is the greatest permissible range of the plate in photographing these nebulae. Before I realized the stringency of this requirement, by making the above simple computation, I spoiled several otherwise fine negatives by allowing the plate to get too far from the center, thus producing elongated star-images.

There is a corresponding elongation in declination, the amount of which can be determined by an adaptation of the formula for reduction to the meridian, but it is practically insensible.

On account of the short focal length of the three-foot mirror, the photographic resolving power of the telescope is much below its optical resolving power. For this reason the photographic

images are less sensitive to conditions affecting the seeing than the visual images. On the finest nights the delicate tracery of bright lines or caustic curves in the guiding-star is as clear and distinct as in a printed pattern. When the seeing is only fair these delicate details are lost, and only the general form of the image, with its two principal caustics, is seen. A photograph taken on such a night is not, however, perceptibly inferior to one taken when the seeing is perfect. When, however, the image is so blurred that its general form is barely distinguishable, the photographic star-disks are likewise blurred and enlarged, and on such nights photographic work is not attempted.

The foregoing account of the small changes which have been made in the Crossley telescope and its accessories may appear to be unnecessarily detailed, yet these small changes have greatly increased the practical efficiency of the instrument, and therefore, small as they are, they are important. Particularly with an instrument of this character, the difference between poor and good results lies in the observance of just such small details as I have described.

At present the Crossley reflector is being used for photographing nebulae, for which purpose it is very effective. Some nebulae and clusters, like the great nebula in *Andromeda* and the *Pleiades*, are too large for its plate ($3\frac{1}{4} \times 4\frac{1}{4}$ in.), but the great majority of nebulae are very much smaller, having a length of only a few minutes of arc, and a large-scale photograph is required to show them satisfactorily. It is particularly important to have the images of the involved stars as small as they can be made.

Many nebulae of HERSCHEL'S I and II classes are so bright that fairly good photographs can be obtained with exposures of from one to two hours; but the results obtained with full light-action are so superior to these, that longer exposures of $3\frac{1}{2}$ or 4 hours are always preferred. In some exceptional cases, exposures of only a few minutes are sufficient. The amount of detail shown, even in the case of very small nebulae, is surprising. It is an interesting fact that these photographs confirm (in some cases for the first time) many of the visual observations made with the six-foot reflector of the EARL OF ROSSE.

Incidentally, in making these photographs, great numbers of new nebulae have been discovered. The largest number that I have found on any one plate is thirty-one. Eight or ten is not an uncommon number, and few photographs have been obtained

which do not reveal the existence of three or four. A catalogue of these new objects will be published in due time.

Some of the results obtained with the Crossley reflector, relating chiefly to particular objects of some special interest, have already been published.* The photographs have also permitted some wider conclusions to be drawn, which are constantly receiving further confirmation as the work progresses. They may be briefly summarized as follows:—

1. Many thousands of unrecorded nebulae exist in the sky. A conservative estimate places the number within reach of the Crossley reflector at about 120,000. The number of nebulae in our catalogues is but a small fraction of this.

2. These nebulae exhibit all gradations of apparent size, from the great nebula in *Andromeda* down to an object which is hardly distinguishable from a faint star-disk.

3. Most of these nebulae have a spiral structure.

To these conclusions I may add another of more restricted significance, though the evidence in favor of it is not yet complete. Among the objects which have been photographed with the Crossley telescope are most of the "double" nebulae figured in Sir JOHN HERSCHEL'S catalogue (*Phil. Trans.*, 1833, Plate XV). The actual nebulae, as photographed, have almost no resemblance to the figures. They are, in fact, spirals, sometimes

* The following list includes all papers of interest:—

"Photographic Observations of Comet I, 1898 (BROOKS), made with the Crossley Reflector of the Lick Observatory." *A. J.*, No. 451, 19, 151; see also *Ap. J.*, No. 8, 287.

"The Small Bright Nebula near *Merope*." *Pub. A. S. P.*, No. 10, 245.

"On Some Photographs of the Great Nebula in *Orion*, taken by means of the Less Refrangible Rays in its Spectrum." *Ap. J.*, No. 9, 133. See also *Pub. A. S. P.*, No. 11, 70; *Ap. J.*, No. 10, 167; *A. N.*, 3601.

"Small Nebulae discovered with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 59, 537.

"The Ring Nebula in *Lyra*." *Ap. J.*, No. 10, 193.

"The Annular Nebula H. IV. 13 in *Cygnus*." *Ap. J.*, No. 10, 266; see also *Publ. A. S. P.*, No. 11, 177.

"On the Predominance of Spiral Forms among the Nebulae." *A. N.*, 3601.

"The Distribution of Stars in the Cluster *Messier 13* in *Hercules*," (by H. K. PALMER). *Ap. J.*, No. 10, 246.

"The Photographic Efficiency of the Crossley Reflector." *Pub. A. S. P.*, No. 11, 199; *Observatory*, No. 22, 437.

"New Nebulae discovered photographically with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 60, 128.

"The Spiral Nebula H. I. 55 *Pegasi*." *Ap. J.*, No. 11, 1.

"Photographic Observations of Hind's Variable Nebula in *Taurus*, made with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 60, 424.

"Use of the Crossley Reflector for Photographic Measurements of Position." *Pub. A. S. P.*, No. 12, 73.

"Discovery and Photographic Observations of a New Asteroid 1899 FD." *A. N.*, 3635.

"Elements of Asteroid 1889 FD," (by H. K. PALMER). *A. N.*, 3635.

of very beautiful and complex structure; and, in any one of the nebulae, the secondary nucleus of HERSCHEL'S figure is either a part of the spiral approaching the main nucleus in brightness, or it cannot be identified with any real part of the object. The significance of this somewhat destructive conclusion lies in the fact that these figures of HERSCHEL have sometimes been regarded as furnishing analogies for the figures which POINCARÉ has deduced, from theoretical considerations, as being among the possible forms assumed by a rotating fluid mass; in other words, they have been regarded as illustrating an early stage in the development of double-star systems. The actual conditions of motion in these particular nebulae, as indicated by the photographs, are obviously very much more complicated than those considered in the theoretical discussion.

While I must leave to others an estimate of the importance of these conclusions, it seems to me that they have a very direct bearing on many, if not all, questions concerning the cosmogony. If, for example, the spiral is the form normally assumed by a contracting nebulous mass, the idea at once suggests itself that the solar system has been evolved from a spiral nebula, while the photographs show that the spiral nebula is not, as a rule, characterized by the simplicity attributed to the contracting mass in the nebular hypothesis. This is a question which has already been taken up by Professor CHAMBERLIN and Mr. MOULTON, of the University of Chicago.

The Crossley reflector promises to be useful in a number of fields which are fairly well defined. It is clearly unsuitable for photographing the Moon and planets, and for star-charting. On the other hand, it has proved to be of value for finding and photographically observing asteroids whose positions are already approximately known.

One of the most fruitful fields for this instrument is undoubtedly stellar spectroscopy. Little has been done in this field as yet, with the Crossley reflector, but two spectrographs, with which systematic investigations will be made, have nearly been completed by the Observatory instrument-maker. One of these, constructed with the aid of a fund given by the late Miss C. W. BRUCE, has a train of three 60° prisms and one 30° prism, and an aperture of two inches; the other, which has a single quartz prism, will, I have reason to expect, give measurable, though small, spectra of stars nearly at the limit of vision of the telescope.

The photogravure of the Trifid nebula which accompanies this article* was made from a photograph taken with the Crossley reflector on July 6, 1899, with an exposure of three hours. It was not selected as a specimen of the work of the instrument, for the negative was made in the early stages of the experiments that I have described and the star-images are not good, but rather on account of the interest of the subject. At the time the photogravures were ordered no large-scale photograph of the Trifid nebula had, so far as I am aware, ever been published.† The remarkable branching structure of the nebula is fairly well shown in the photogravure, though less distinctly than in the transparency from which it was made. The enlargement as compared with the original negative, is 2.9 diameters, ($1^{\text{mm}} = 13''$). The fainter parts of the nebula would be shown more satisfactorily by a longer exposure.

DESCRIPTION OF PROFESSOR KEELER'S MERIDIAN CIRCLE.

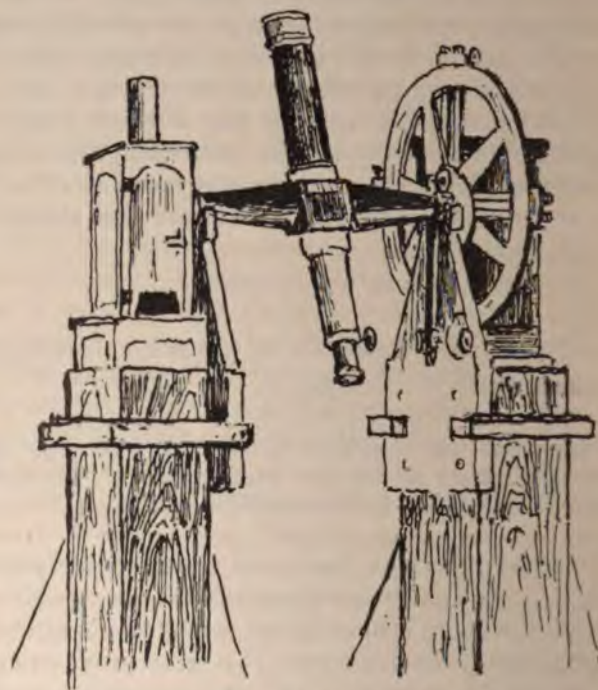
[The instrument was constructed by Professor KEELER in 1877, at which time the sketch on the next page was made. The following description of it was written by Professor KEELER in 1885.]

"The telescope of the instrument was originally part of a spy-glass. It was separated at the eye-end of the outer tube and the two parts screwed into an axis of wood (cedar), turned into the shape shown in the illustration. The pivots were formed by copper ferrules driven on and turned at the same time, as nearly equal as possible. They rested not in Y's but in semicircular bearings of brass, formed by turning an aperture in a brass plate which was afterwards cut into two pieces. The axis was rendered horizontal by a small ordinary spirit-level (no graduation), fastened on a wooden bar, having at the ends brass uprights, with (I think) square ends, to rest on the pivots. One of the brass bearings of the pivots was adjustable. The cross-wires were spider-lines cemented to a small leaden ring, movable across the field of view by the screw shown near the eye-piece, a spring being placed

* Omitted here, as it has already been printed in these *Publications*. See *A. S. P. Publ.*, No. 74, p. 89.

† Since then a photograph by Dr. ROBERTS has appeared in *Knowledge*, No. 23, 35, Feb. 1900.

opposite to keep the ring pressed against the end of the screw. These wires were illuminated by a small kerosene lamp in the box shown on the left, the axis being perforated and an elliptical reflector of paper with central aperture being placed at the intersection of the telescope and axis. The circle was made of wood, fastened together in sections. . . . The graduated circle was



PROFESSOR KEELER'S MERIDIAN CIRCLE.

an engraved paper protractor divided to $15'$, pasted on before the central part was cut out. It was originally designed to read by two pairs of diametrically opposite verniers, but I think only one was ever finished. I do not remember what was its least count. [Possibly no vernier; only an index.] The readings are given to single minutes, perhaps, however, by estimation. The clamp with micrometer tangent screw was an improvement designed but never executed.

"I think the eye-piece consisted of a single convex lens.

"The piers were pieces of 6 in. $\times$ 8 in. pine sunk into the ground about two feet.

"The clock (shown behind the circle) was a small kitchen affair, and kept execrable time. It had no second-hand, and the observer made an observation by looking at the clock-face after the star was on one of the wires, mentally allowing a little for the time necessary to get up from his position at the telescope and go to the clock, and estimating the seconds as best he could.

"The instrument was protected when not in use by a cover or hood made of wood, and roofed with tarred paper, which rested upon the cleats nailed around the tops of the piers.

"To the north the horizon was invisible on account of the forest, but to the south a long sight could be obtained across the salt marsh, and a tall pine-tree nearly on the meridian served for the purposes of collimation."

A POPULAR ACCOUNT OF THE CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION TO
SILOAM, GEORGIA, MAY 28, 1900.

BY CHARLES BURCKHALTER.

The expedition from this observatory to observe the late eclipse was at the sole expense of Mr. JOHN DOLBEER, of San Francisco, who also paid my salary while absent from the observatory. The lantern-slides and other work sent out since my return have also been at his expense, and there yet remains a considerable balance which he refuses to receive, thus leaving me in possession of riches I scarcely know what to do with,—to me a most novel and unique experience. Mr. DOLBEER had generously settled the matter nearly a year before it was necessary for me to start; the Board of Education of the city of Oakland and Superintendent McCLYMONDS had given me the necessary leave of absence, also granting permission to use any part of the instrumental equipment of the observatory, so that I had ample time to prepare. The above happy condition is not always realized, and many a blunder has been made because preparations had to be rushed. The very greatest care must be observed in every detail of the preliminary arrangements since the result depends upon the rapid work of a few seconds. When I shipped the instruments, six weeks before I started myself, they were as ready as I could make them. Freight is an uncertain

quantity across the continent, but the instruments reached their destination about three weeks before I arrived myself.

My principal instrument was the Pierson eclipse-telescope, presented by Mr. WM. M. PIERSON to this observatory for the expedition to Japan in 1896, to which was added the duplicate lens presented by Dr. GEO. C. PARDEE for the Indian Expedition, making really a double telescope. The lenses are four inches aperture and fifteen feet focal length. A new equatorial mounting was made during my leisure time upon the same principles as that used in India, which is described in the Indian Report.* Some new plate-holders were added, my programme being arranged for five exposures in each telescope, if time permitted. Nine of these were to have the exposures controlled, the remaining one uncontrolled, for comparison. The proposed exposures were printed in No. 73 of these *Publications*, but the persistent grayness of the sky during the two weeks preceding the eclipse led me to change the two ten-second exposures to eight seconds, as I felt confident that ten seconds would over-expose the sky; and the result proves the wisdom of the change.

I started from home on April 24th, and had the unexpected pleasure of finding myself in the same car with Professors CAMPBELL and PERRINE, of the Lick Observatory Expedition, for the long ride across the continent.

I expected to establish the station at or near Union Point, Georgia; but upon arrival observation proved that the town was about seven miles northwesterly from the central line of totality, and I could not afford the serious loss of time this distance from the central line would cause. This was a great disappointment to me, as well as to Mr. WM. HART, and others, who had given me much valuable information, and who were also to be volunteer assistants. After some exploring to the southeast, I went to Siloam, a little village in the right direction. The maps issued by the Naval Observatory placed the village about a mile southeasterly of the central line, but preliminary observations placed it about one and one half miles northwesterly; but this gave me practically the full time of totality, and I decided to establish the station in this quiet little village, it having railroad connection, so that the instruments could be easily transferred.

The conditions of the situation selected for the station were just about perfect; a near-by empty store building—the property

* See also these *Publications*, No. 65.



THE CORONA, MAY 28, 1900.—NEGATIVE NO. 6.
CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, SILOAM, GEORGIA.

Exposure given, counting from Sun's center.	At—	16'	20'	24'	28'	32'	40'	50'	60'	80'	110'
	Time—	0.04	0.32	0.50	1.38	1.76	2.40	3.20	4.00	5.00	8.00

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of Mr. STANLEY — was placed at my disposal, giving me a splendid place to unpack my instruments, and furnishing protection until the temporary observatory could be erected. My boarding-place was within a stone's throw. A well of good water was near by, which, with buckets and barrels always kept full, furnished protection against possible fire. Several stores and blacksmith and wagon shops, from which volunteer help to "give us a lift" could be had for the asking at any time, and, lastly, a convenient lumber-pile, to which I was invited to "help myself," completely filled all important requirements.

The readiness of the villagers to give me any help in their power was very gratifying, and fully repaid me for the idle curiosity they sometimes manifested. Many were with me much of their leisure time, and I was seldom entirely alone; but they were so good-natured and good-humored about it that I could not but let them say and do as they pleased without protest, especially as many considered this expedition "the biggest thing that ever happened to Siloam!"

The colored folk were immensely interested and impressed, the whole surrounding neighborhood, it seemed to me, coming to see and marvel. They had many curious ideas, and even some of the whites were lacking in a very deep knowledge of things "eclipse-wise." Many thought it was a money-making scheme, and what I intended to charge for admission was a very important question, frequently asked. Another idea was that the eclipse could be seen only from the inside of my observatory. I had a camera with me that at once became very popular. Requests to take their pictures were frequent, and sometimes persistent, and as all I did was "without money and without price," business would have been brisk if I had had the time to attend to it. But, taken altogether, my stay of five weeks in the village was as pleasant as one could expect while upon an eclipse expedition, which means hard work, worry, and anxiety, for the villagers fully sustained the great reputation of the Southern people for hospitality, and I received attention and favors that I had no right to expect. Just here I wish to express my appreciation of the high moral tone of the community, for, with a population of only one hundred, including the immediate neighborhood, it sustains two white and two colored churches, and during my stay I did not hear a single profane word by a citizen of this model village, situate in the heart of the "Cotton Belt."

By the kindness of J. CONKLIN BROWN, of Berkeley, who had lived for thirty years in Greensboro — seven miles distant — I was given letters that brought a perfect deluge of offers of help. With the friends at Union Point also doing all in their power to help me, this placed my enviable position in strong contrast with the lone Camp Pierson in India, where I was placed entirely upon my own resources. My greatest need seemed to be some one to help me decline the very pressing invitations I so frequently received to visit these friends at their homes.

As an unsophisticated Yankee in the Southland, unused to Southern ways, I naturally made many little slips that were not considered "just the thing." The smiles at my prefixing "Mister" to the name of my colored helper caused me to change it to "Colonel," which was entirely satisfactory to everybody, and did not materially increase the number of colonels. As he reminded me of my faithful Indian cook, Mustapha, his full and official title is now "Colonel Mustapha Berry Evans," and he now enjoys among his friends the reputation of being an astronomer of no mean ability.

Within a week the telescopes were in rough position, my observatory, sixteen by twenty-four feet floor-space, and eight to twenty-two feet high, was completed, and I was ready for the worst part of the work — the little things. The weather and sky were superb, everything seemed to prosper, and I began to look about for assistants; for I had undertaken the expedition alone. These were chosen from among the people of the village. I had received several offers of help from Atlanta, Athens, and other towns; but I needed assistants close at hand, in order to have them practice their parts often, skill being of more importance with me than knowledge. Besides, I did not have to *unlearn* them. They were clerks, merchants, blacksmiths, and farmers by occupation. Their work was simple, yet the success of the expedition rested largely upon them, for I could not have accomplished one half the programme by myself; and the fact that the entire programme went through without a hitch, proves how faithfully and well they did their work. We had many rehearsals, — two during daylight, the remainder at night, each time going through the full programme several times, just as we expected to do on eclipse day. There were two men trained for each important place and an extra man for emergencies.

The weather, that overshadowing question at eclipses, became

unsettled about the 18th, and my records show that I had only about one chance in ten for clear weather—and I have since heard that there were but two clear days in the following six weeks! We had some severe thunder-storms with heavy wind. One squall made the buildings in the village crack, and I feared for a time for the safety of the temporary observatory; but it gallantly rode out the storm, a thorough soaking to my bed and some books being the only damage.

On eclipse day the sky was about three tenths cloudy near the eastern horizon, the wind was southeast, drifting the clouds toward me, and for a time I felt intensely anxious; but by first contact the sky was nearly clear, my only fear being that the drop in temperature would chill the moisture-laden air again. I had an hour of doubts and fears; but the sky remained clear, but very gray, which confirmed me in my determination to cut my two ten-second exposures to eight seconds.

The programme went through perfectly. Not a word was spoken except the ones agreed upon. Each one had an opportunity for a short glance at this, Nature's greatest phenomenon; and just four seconds after the last exposure was completed a beam of sunlight brilliantly proclaimed that the eclipse was over. It began clouding up immediately, and we had "a right smart" sprinkle before noon, which I observed with genuine satisfaction, for the long strain and anxiety had ended with totality.

Two plates were developed at once in the closet under the stairs of Mr. FILLINGHIM's house; the remaining eight were taken to Professor BARNARD, at Yerkes Observatory, and to Secretary ZIEL, at home, for expert development. The two plates developed had received extremes of exposure for the inner corona, and as they were respectively slightly under and over exposed, as I had hoped, I knew the plates with intermediate exposures, upon which my hopes were centered, would be all right. So I began packing up the instruments, leaving the village four days later, thus breaking my best record in packing up.

The results obtained will be more fully discussed in the forthcoming report, and the following description of the more characteristic negatives must suffice here.

No. 1 is a curiosity in at least one respect—the extreme inner corona is thoroughly *under-exposed*. At the Moon's edge the exposure was only 0'.02. The prominences seem to have been

perfectly exposed, being full of delicate detail, the chromosphere was over-exposed, while the corona is so faint that by hard printing it can be printed out entirely, leaving only the prominences and chromosphere.

No. 5 was exposed eight seconds without control, for I wanted one uncontrolled plate to compare with the others. It is an excellent negative, but shows nothing whatever near the Moon's limb.

No. 6 was made during the same interval, receiving precisely the same total exposure as No. 5. These plates are, therefore, strictly comparable. The exposure of No. 6 at 16' from the Sun's center was 0'.04, thus giving the corona at 110' distance two hundred times more exposure than at 16'. This is my second-best negative, the printing qualities being exceptionally good.

No. 7 shows a greater extension on the eastern side of the Sun than any other plate. It can be traced with certainty to 84'. The exposure at 16' was 0'.08—too much for best results. It shows all the prominences, but not in such detail as other plates.

No. 8 is very much the best negative from a scientific standpoint, but unfortunately it has some specks on the film, and besides has been somewhat over-developed. It is a hard printer, and, so far, I have not been able to obtain results that are reasonably satisfactory.

No. 9 and No. 10 have exquisite inner detail, but not such good extension.

For the Pierson telescope, using Cramer crown plates, 0'.04 to 0'.05 was the proper exposure for the extreme inner corona, and 8".00 gave me the best extension. On the Chabot Observatory-Pierson expedition to India, the shortest exposure was 0'.08. The Indian corona was much brighter than the recent one, and 0'.03 would have been about right there, but such an exposure with a four-inch lens with fifteen feet focus would have been thought ridiculous at that time. While the shortest Indian exposure was about three times too much for best results, it gave me the very knowledge I needed to make the Georgia expedition a success. I asked advice from no one this time, but used my own judgment, No. 8 being my ideal plate. The exposure, it seems to me, is precisely right in every part.

I cannot close this article without grateful acknowledgments to the Southern Pacific Company, for half-rates on freight, and to Mr. HORSBURGH, of the Passenger Department, for half-rates of fare; also to the Northern Pacific Railway and the Pacific

THE CORONA, MAY 28, 1900.
CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, SILOAM, GEORGIA.



From Negative No. 1, from 0 to 4th second of totality:

Exposure given, counting from Sun's center. }	At—	16'	18'	20'	24'	28'
		s.	s.	s.	s.	s.
	Time—	0.02	0.08	0.18	0.42	0.78



Part of Negative No. 10, six seconds exposure, from 77th to 82d second (inclusive) of totality, from a print made from a negative, made from a positive enlarged 6 diameters.

Exposure given, counting from Sun's center. }	At—	16'	18'	20'	24'	28'
		s.	s.	s.	s.	s.
	Time—	0.06	0.12	0.25	0.62	1.16

Coast Steamship Company, for half-rates over their lines. In fact, it were better to thank every person with whom I came in contact, for without exception I was helped by everybody that could help me. I wish to express my appreciation of the kindness received from Judge HART and his nephews, WILLIAM and H. B. HART, of Union Point, and to thank Mr. LITTLE, Mr. ROSSMAN, and many others of Greensboro for their splendid hospitality. My stay in the Sunny South was made so pleasant that the name of Georgia is synonymous with friendship, hospitality, and good-will.

The following assistants have placed me under obligations and aided science: J. T. BRYSON, D. A. SAGGUS, J. M. SAGGUS, H. H. ANDREWS, A. S. ONEAL, W. J. ONEAL, E. J. STANLEY, JNO. T. BOSWELL, CLAY FILLINGHIM, all of Siloam; and Mrs. ROBINSON, of Greenboro, who made drawings of the corona.

Finally, I must not forget "Colonel Mustapha" Berry Evans, the colored wag of the village, who carries the mail from the post-office to the station four times a day for less than three dollars a month, but manages to make his living with less work than any man in the neighborhood. He was my helper throughout. There is a smile in the story of how he would have assisted me more if I had applied to him in time. I was making sextant observations for position one night, and this aroused his curiosity. In answer to his question of what I was doing, I told him I was trying to find out exactly where I was. His amazement and pity for my ignorance found expression in "Foh de Lawd's sake! why did n't you ask me? I was done bo'n and brought up heah! You's *right heah in Siloam*. I reckon you's foolin' me!"

CHABOT OBSERVATORY, OAKLAND, CAL., September, 1900.

THE CROCKER EXPEDITION TO OBSERVE THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900.

BY W. W. CAMPBELL AND C. D. PERRINE.

The generosity of WILLIAM H. CROCKER,* of San Francisco, enabled the Lick Observatory to send an expedition to observe the total solar eclipse of May 28, 1900. The organization of

*Mr. CROCKER's brother, the late Colonel C. F. CROCKER, Regent of the University of California, had similarly befriended the Lick Observatory, in the Expeditions sent to Cayenne in 1889, to Japan in 1896, and to India in 1897-98.

the expedition was begun by Professor KEELER, Director of the Observatory, at the middle of March. The members of the staff detailed for this duty were the writers of this article. The preparations of the instruments and equipment were necessarily very hurried, but Professor KEELER placed the resources of the Observatory at our disposal, and the heavy packages were ready for shipment on April 11th. However, several new prisms and lenses ordered from the Eastern makers arrived so late that the three new spectrographs could not be completed before the shipment was made. They were finished at the station, only a day or two before the eclipse. The observers left San Francisco on April 24th, via El Paso and New Orleans.

The path of totality began at sunrise in the Pacific Ocean, swept across Mexico, the southeastern portion of the United States, the Atlantic Ocean, Portugal, Spain, and Algiers, and ended at sunset in southeastern Egypt. Observations in the elevated regions of Mexico were precluded by the low altitude of the Sun; and the path available in the United States for occupation by an observing party lay along the line joining New Orleans, Louisiana, and Norfolk, Virginia. The cloud observations secured in May and June of the three preceding years by the Weather Bureau, indicated that the chances for clear sky were best in eastern Alabama and western Georgia, where the foothills of the mountains reach nearly to the shadow-belt, and where the height of the station above sea-level would be the greatest. Stations to the east of this locality would have the compensating advantage of a higher Sun. As the eastern observatory parties would probably select stations well to the east, it was decided that our party should locate in western Georgia, at the city of Thomaston.

The observers reached Thomaston on the evening of April 30th, and were warmly welcomed by the Mayor, the County School Commissioner, and other prominent citizens. The next forenoon, in company with these gentlemen, we were driven over the surrounding country—beautiful rolling country, grown over with forests of pine and oak, or just sown with cotton-seed—in search of a suitable camp. A site was selected in an open field, gently sloping to the west, about one half mile northwest of the city, but still within the city limits.

The preparation of the camp began at once. Relegating the carpentry, masonry, and excavating as far as possible to local



GENERAL VIEW OF THE OBSERVING-STATION OF THE CROCKER ECLIPSE EXPEDITION,
THOMASTON, GEORGIA

workmen, our own time was very fully occupied, up to the last minute, with completing, mounting, and adjusting the instruments, and in training the assistants to the programme of observations.

The 40-foot photographic telescope was mounted almost precisely as it was mounted in India in 1898. A wooden tower, pyramidal in form, was constructed to support the 5-inch lens. A larger tower of the same form surrounded the lens-tower, so that, when covered with canvas on the morning of the eclipse, the wind could not vibrate the inner tower and the lens. The outer tower also supported the upper end of the canvas tube of the camera. The lower end of the canvas tube, the steel track for the traveling plate-holder, and the clock were in a pit excavated in the red clay soil to a depth of about nine feet. A large canvas sheet covered the pit and its approaches, to keep the rain from entering it.

The four spectroscopes and one medium-sized camera were mounted on a large polar axis, driven by a clock placed at the end of a sector $10\frac{1}{2}$ feet in length.

Two medium-sized photographic telescopes and four small cameras were mounted on another polar axis, driven by a clock at the end of an $8\frac{1}{2}$ -foot sector.

Brick piers extending to a depth of two feet were constructed to support the polar axis; and similar piers served to support the chronometer and the sextant basin of mercury. The soil under the camp transmitted vibrations with but little loss of strength. It was impossible to make sextant reflection observations if any person was walking within twenty-five or thirty yards of the observer.

A very complete dark room, six by ten feet, with water-pipes for supply and waste, was constructed.

Sextant observations of the Sun and of the stars, for determining the latitude and longitude of the camp, were secured soon after our arrival. Thomaston is situated at the end of a branch line of the Central of Georgia Railway; and the regular time-signals do not go over this branch. At our request, the officials of the Western Union Telegraph Company transmitted the signals of the U. S. Naval Observatory clock in Washington daily to Thomaston, for comparison with our local time. As a result of six days' observations, and telegraphic comparisons, the longitude of the station was found to be

$$5^{\text{h}} 37^{\text{m}} 18^{\text{s}}.8 = 84^{\circ} 19'.7.$$

The observed value of the latitude is $+ 32^{\circ} 53'.7$.

These values are approximate, since the final reductions have not been completed. The station was one half a mile northwest of the central line assigned by the American Ephemeris, and very close to the British Almanac line.

As in other recent expeditions sent out from here, dependence was placed on volunteer observers to take the greater number of the photographs. Seven astronomers from a distance volunteered to serve, at their own expense, and seven additional assistants from Thomaston offered their services. These gentlemen were: Professor Dr. A. A. NYLAND, Director of the Utrecht Observatory, Utrecht, Holland; Dr. J. H. WILTERDINK, Astronomer in the Royal Observatory, Leiden, Holland; HEBER D. CURTIS, Professor of Mathematics and Astronomy in the University of the Pacific, San José, Cal., and now Fellow in Astronomy in the University of Virginia; JOHN A. MILLER, Professor of Astronomy in the University of Indiana; W. P. RUSSELL, Professor of Astronomy in Lincoln University, Lincoln, Illinois; A. H. BUCHANAN, Professor of Mathematics and Astronomy in Cumberland University, Lebanon, Tenn.; G. E. LUMSDEN, Esquire, President of the Toronto Astronomical and Physical Society; Captain J. R. ATWATER, Mayor of Thomaston; Dr. EUGENE T. BOOTH, of Thomaston; Professor REMBERT G. SMITH, President of the R. E. Lee Institute, Thomaston; Professor GEORGE K. ORR, of the Lee Institute; Professor JOSEPH E. HANNAH, Col. JOHN H. LEWIS, and ALBERT A. MATTHEWS, Esquire, of Thomaston.

We wish to acknowledge very fully the able and faithful services rendered to the expedition by these assistants. They multiplied the quantity of useful results obtainable several fold.

The assistants were drilled on the three days preceding the 28th, until every man felt confident that he could carry out his share of the programme, in the eighty-five seconds of totality. The delicate parts of all the instruments were examined, and all the adjustments were tested, so far as possible, on the day before the eclipse. The Weather Bureau predicted unusually favorable atmospheric conditions for the eventful morning along the entire line of totality. The night of the 27th was devoted to "backing" the plates and filling the plate-holders, and the sky was beautifully clear, at least up to 3:00 A.M. On rising for the day's work, at 4:00 A.M., the sky was completely clouded!

The clouds were gradually dispelled by the heat of the Sun, until at the time of first contact, the sky was nearly clear. Sextant observations for time were secured, and reduced; and, a light breeze springing up, the wind-screens were placed on the tower, and on the windward side of each polar axis. Five or ten minutes before totality the instruments were directed to the Sun and the clocks started, and the assistants took their places. Attention was called to the large masses of clouds rapidly approaching from the southwest. Up to two or three minutes before totality, it seemed certain that the corona would be completely hidden; and up to one minute thin clouds threatened to cut off portions of it. Fortunately, there was time to secure the observations; and about one minute after totality the clouds obscured the Sun. The state of the air had been such that the lowering of its temperature as the eclipse came on was sufficient to form clouds. In another half-hour these had disappeared; and a second set of time observations were secured just after the last contact. The sky throughout the morning was quite white.

The programme of observation, with the eleven instruments, and by two visual observers, was completely carried out, except that on one of the spectroscopes a clock for giving uniform motion to the plate-holder refused to work just at the beginning of totality. However, it was quickly righted, and the desired long exposure to the corona spectrum during totality, and the exposure with moving plate-holder at the end of totality, were secured; so that only one-third of the work with this instrument was lost.

Owing to the great distance from the Lick Observatory, we could not follow the practice of the Eastern parties in taking the plates home for development in cool dark-rooms. It was necessary to develop at Thomaston. The week following the eclipse was very hot, both day and night. The dark-room was uninhabitable by day; but after ten o'clock at night, by the liberal use of ice, the temperature of the room could be brought down to between seventy and seventy-five degrees; and the development was carried on between that hour and daylight.

As a result of this expedition, the Observatory possesses a large number of very beautiful and very valuable photographs of the eclipse phenomena, as well as several valuable results obtained from the visual observations.

The ninetieth-meridian times of beginning and ending of the total phase for the position of the station, as computed from the

American Ephemeris data by Messrs. PERRINE and CURTIS, were—

for beginning, May 28th, 7^h 38^m 17^s.3 A.M.

for ending, 7 39 42.2 A.M.

The computed duration was 1^m 24^s.9.

The duration as observed by Mr. PERRINE, in the camera-end of the 40-foot telescope, was 1^m 23^s.7; and by the naked-eye observers it was certainly more than 1^m 25^s, and may have been as much as 1^m 27^s. The signal "Go" was given by Mr. PERRINE, at the instant of totality, as a signal to the man at the chronometer to begin the counting of seconds aloud, as a guide to the observers. The signal did not refer to the instant when the crescent of light disappeared, but to an instant—possibly one and a half seconds later—when the last points of light, shining evidently through the depressions in the Moon's edge, vanished completely. At the end of totality, the first points of returning light were visible to Mr. PERRINE after a duration of 1^m 23^s.7. To two naked-eye observers—Messrs. CURTIS and RUSSELL, detailed for this purpose—the light, probably the crescent of sunlight, returned at 1^m 25^s.3 after the signal "Go." It is probable, therefore, that the interval between the disappearing and reappearing crescents was about 1^m 27^s. At any rate, it is certain that the signal given by Mr. PERRINE, for the disappearing points of light, was perceptibly later than the instant when, to the naked eye, the eclipse seemed to be total.

The times of beginning and ending noted by Mr. PERRINE were—

7^h 38^m 10^s.1 A.M.

7 39 33.8.

The total phase, therefore, occurred between seven and eight seconds earlier than the time assigned by the Ephemeris.

Eight photographs were secured with the 40-foot telescope during totality, on Seed's No. 27 plates, single-coated and "backed," with exposures varying from half a second to sixteen seconds. They are of great excellence. The structure of the prominences, the thick chromospheric stratum, and the coronal streamers are beautifully shown. The hoods of streamers inclosing the prominences, so remarkable a feature on the Indian coronal photographs of 1898, are not conspicuous on the present photographs, though certainly present in the case of one prominence of medium size. There are several minor indications of a connection between



THE PROMINENCES, CHROMOSPHERIC LAYER AND EXTREME INNER CORONA, ON THE WEST SIDE OF THE SUN.
(EXPOSURE ONE-HALF SECOND, NEAR THE END OF TOTALITY.)
CROCKER ECLIPSE EXPEDITION, THOMASTON, GEORGIA.

the prominences and the streamers; but further evidence must be secured at future eclipses, before the question will approach solution.

A number of fine small-scale photographs of the corona were obtained with the shorter telescopes, suitable for studying the details and forms of the streamers in the regions of medium brightness.

Several of the shorter cameras were devoted to a determination of the conditions best adapted to recording the faint outer streamers of the corona. Several varieties of plates—single and triple coated, slow, medium, and rapid—and exposures from short to very long, were tried. It had seemed to us that the question of recording the outer extensions was one of contrast; and that slow plates, with normal exposure and full development, would give the best promise of success. The results justified this conclusion. The greatest extensions, about four solar diameters on the west side, were secured with a camera whose ratio of aperture to focus was 1 to $3\frac{1}{2}$, and an exposure of twenty seconds on a lantern-slide plate. The inner corona, as was expected, was very much over-exposed. Visual observations of the corona by Messrs. LUMSDEN, BUCHANAN, CURTIS, MILLER, and HANNAH agreed very well in placing the lengths of the visible streamers on the west at about 3 or $3\frac{1}{2}$ diameters, and somewhat shorter than this on the east.

The objective-prism spectrograph, with two 60° prisms in front of a 2-inch aperture and 60-inch focus objective, furnished a fine photograph of the bright- and dark-line spectra of the Sun's edge at the end of totality, as the edge was gradually uncovered by the Moon. This is on a plate moved by the clock which refused to run at the beginning of totality, referred to above. This plate, limited in size by the construction of the instrument, extends from a little below the *b* group to a little above *K*. It contains about 600 bright lines, sharply in focus, as well as the dark-line spectrum to which the bright lines gave way as the Sun reappeared. It is about six inches in length.

A 20-second exposure on the spectrum of the corona, with the same instrument, records the prominences in their principal chemical elements, as well as the two coronal rings at $\lambda\lambda$ 369 and 423.

The structure of the green coronal ring, on the west side of the Sun, as recorded by an objective grating spectrograph, agrees, in general, with that of the ring as photographed with the same

instrument in India. The coronal material radiating the green light is heaped up in the sun-spot regions very markedly. The position of the ring is $\lambda 5303 \pm$, as determined from the Indian plates. The eastern half of the ring was not recorded.

A photograph of the spectrum of the inner corona, taken with a slit spectroscope, is free from dark lines, as in the case of the Indian photographs.

Very interesting and successful observations of the shadow bands were made at the beginning and ending of totality by Messrs. BUCHANAN and LUMSDEN. White sheets were stretched on the ground, on which the bands were well observed. The directions of the bands were fixed by placing long rods of wood on the sheets, and adjusting them, during the second of time that the bands lasted, to the proper direction. The positions of the rods were afterwards determined to be:—

For the beginning, N. 37° W., by Professor BUCHANAN.

For the ending, N. 42° W., by Professor BUCHANAN.

For the ending, N. 39° W., by Mr. LUMSDEN.

The bands were traveling toward the northeast. These gentlemen also secured very satisfactory drawings of the outlines of the corona.

The sky seemed slightly brighter during totality than at the Indian eclipse. There would have been no difficulty in reading ordinary print.

Portions of two of the large-scale photographs of the corona are reproduced to accompany this article. It should be said that the finer details of the photographs are almost entirely lost in the process of reproduction. There appears to be no known way in which such pictures can be satisfactorily copied by mechanical processes.

It will be understood that the foregoing account of the work of the expedition is of a general nature. The detailed study of the photographs and of the individual observations will be made as soon as possible, and the scientific results will be published later.

The expedition received valued favors from many sources, which we gratefully acknowledge.

The Southern Pacific Railway Company assisted the expedition in every possible manner. We are especially indebted to General Passenger Agent T. H. GOODMAN; General Freight Agent Wm. SPROULE; the officials of the freight offices in San



THE NORTH POLAR STREAMERS OF THE CORONA.
(EXPOSURE 16 SECONDS, WITH THE 40-FOOT CAMERA.)
CROCKER ECLIPSE EXPEDITION, THOMASTON, GEORGIA.

José and New Orleans. When the instruments were detained a week in New Orleans by the floods, and a dangerous delay was threatened, the kind offices of the Company were exerted to secure their shipment on the first train leaving the city for Atlanta.

Scarcely second in importance were the favors extended at every opportunity by the officials of the Central of Georgia Railway. We recall with pleasure the assistance afforded by President J. M. EGAN; by General Passenger Agent J. C. HAILE; by Col. D. W. APPLER, in charge of the company's interests in Atlanta; by Traveling Passenger Agent WARREN H. FOGG; and by Agent WHITE, at Thomaston.

The success of the expedition was promoted in every possible manner by the officials of the city of Thomaston, by the officials of Upson County and by the leading citizens. Hon. JAMES R. ATWATER, Mayor, made it a daily duty to inquire after our needs, and to supply them as far as possible, and promptly. Captain ATWATER's constant thoughtfulness and helpfulness will not be forgotten. Among the special services rendered by the city, through its worthy Mayor, we may mention that excellent special watchmen were furnished for the camp, without expense to us. This service was executed in a satisfactory manner, and not even a nail was missing at the end of our five weeks' residence. City Marshal McDANIEL assisted us very efficiently in many ways. The genial night-watchman, Mr. HAINSBERGER, was thoughtfully helpful on many occasions.

The Hon. R. D. SHUPTRINE, County School Commissioner; Dr. HERRING, County Trustee and citizen; and many other leading members of the community rendered services which will be gratefully remembered.

Professors MILLER and RUSSELL were constantly at the station during the three days preceding the eclipse, and were very efficient assistants in completing many of the minor mechanical details.

We desire to make special acknowledgment of the voluntary services rendered by Professor CURTIS. He was with us ten days. He assisted in the final installation of the instruments. He was placed in charge of the polar axis carrying the six cameras, and at the head of the observing party operating them. We do not see how we could have dispensed with his services, nor how any one could have met the exacting demands better than he did.

It may not be out of place to refer to the complex requirements of a successful eclipse expedition. The installation of a dozen instruments in a permanent observatory, with skilled and technical assistance available, so that all the instruments will work well when required, is not a simple matter. The dozen instruments at a temporary eclipse station, where skilled assistance is not available, must work equally well *at a given second of time*.

After our eclipse duties were over, we visited, with pleasure and profit, the most of the leading observatories of the country, and attended the annual meeting of the Astronomical and Astrophysical Society of America, in New York; returning to the Lick Observatory in the last week of July.

OBSERVATIONS OF THE ZODIACAL LIGHT FROM JANUARY, 1899, TO JULY, 1900.

BY FRANCIS J. BAYLDON, R. N. R.

(ABSTRACT.)*

I. GENERAL REMARKS.

All observations were made at sea. From January to August, 1899, our voyages were from Sydney to Wellington (N. Z.), Suva (Fiji Is.), Honolulu, Victoria (Vancouver Is.), and Vancouver (B. C.). Since August, 1899, the voyage is from Sydney to Brisbane (Queensland), Honolulu, Victoria, and Vancouver. The round voyage from Sydney to Sydney takes nine weeks, including two weeks' stay at Vancouver. In Sydney we remain for three weeks. If necessary, the average speed of the ship may be considered as fourteen knots per hour.

From January to August, 1899, the observations were chiefly made during my watch on deck from 8 to 12 P. M. aboard the R. M. S. *Aorangi*. From August to the present time they have been made from 7 to 9 P. M., and from midnight to 4 A. M. aboard the R. M. S. *Warrimoo*.

*Mr. BAYLDON'S paper is too extensive to be printed in full in our *Publications*. With his consent, we therefore present this abstract, which gives in full the notes made on a few nights. The original paper is on file in the library of the Society.—THE COMMITTEE ON PUBLICATION.

The star-charts chiefly used are PROCTOR'S "Small Star Atlas," and an old "Celestial Atlas" by JAMIESON, published at the beginning of the century. As both outlines and the line of central axis are given, it is hoped that any clerical errors or mistakes will be easily recognized.

A great many of the observations were corroborated by officers or passengers who happened to be handy. Observations of the Light are very rare in the Pacific between November and April on account of the great amount of cloud then present.

Latterly, I have endeavored to form some idea of the intensity of the Light by imagining a table of intensity, ranging from 1 = Light just visible as a diffused glow, outlines unobtainable, to 10 = very bright, equal to the brightest portions of the Galaxy, *at their brightest*.

II. OBSERVATIONS.

1899. *January 9th*—Lat. $13\frac{1}{2}^{\circ}$ S.; Long. 177° W.

8 to 10 P. M.—Very clear night. Light very distinct, considerably brighter than the Galaxy. The western cone very bright to an elongation of about 105° . Diffused light widely extended on both sides. Beyond the apex, diffused light appeared alternately nearer the *Pleiades*, and α and β *Arietis*, and *Aldebaran* and α and γ *Ceti*.

In *Sagittarius*, *Capricornus*, *Aquarius*, and *Pisces*, the line of central axis lay from 4° to 0° south of the ecliptic, the breadth of the Light ranging from 30° at an elongation of 30° , to 12° at elongation 105° .

In *Aries* and *Taurus* the line of central axis lay from 0° to 1° north of the ecliptic, the breadth of the Light varying from 12° to 8° at elongation 140° . The Gegenschein distinct from near Σ to β *Geminorum*, oval-shaped, but the glow of *Mars* completely spoils observations.

February 1st — At Comox, Vancouver Island, Lat. $49\frac{1}{2}^{\circ}$ N.; Long. 124° W.

8 P. M. to 11:30 P. M.—Very clear, frosty night. Thermometer 20° F. Magnificently clear air. The western cone as bright as the Galaxy in *Perseus*, extending to the *Pleiades*, about 65° altitude, 20° broad in *Aries*, lower portion apparently enormously displaced to the northward in *Andromeda* and *Pegasus*, but land interfered with observations at a low altitude, as did the Galaxy and *Mars* at very high ones. The Light was distinctly

visible from the Gegenschein to near the eastern horizon below the Sickie. Apex of western cone at 105° elongation. At 11:30 clouds formed and the glow of Aurora Borealis appeared to the northward. Outlines of the Light were obtained as follows:—

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
2° N. of γ <i>Pegasi</i> .	δ <i>Piscium</i> .	ι <i>Ceti</i> .
α <i>Arietis</i> .	ϵ <i>Arietis</i> .	2° S. of ξ' "
$5''$ N. of <i>Pleiades</i> .	<i>Pleiades</i> .	1° N. of μ <i>Tauri</i> .
	β <i>Tauri</i> .	

[Galaxy intervenes.]

$\frac{1}{2}^\circ$ N. of α *Geminorum*. | 1° S. of ι *Geminorum*. | δ *Geminorum*.

G e g e n s c h e i n .

Near μ <i>Leo Majoris</i> .	1° S. η <i>Leo Majoris</i> .	α <i>Leo Majoris</i> .
" ζ " "	Just N. of β <i>Virginis</i> .	3° N. of η <i>Corvi</i> .
β " "	2° N. of α "	4° N. of γ <i>Hydræ</i> .
3° N. of δ <i>Virginis</i> .		
Just N. of ζ "		

Diffused light apparently extended through *Triangula* about to β *Andromedæ* and wholly embraced the Square of *Pegasus*.

May 9th—Lat. 33° N.; Long. 147° W.

10:45 to 11:15 P. M.—Magnificent observations. Light faint, but distinctly outlined. Western branch just touches *Virgo*. Rising Galaxy humbugs eastern horizon. Night very clear. Outlines as follows:—

NORTH.	CENTRAL AXIS.	SOUTH.
1° N. of α <i>Geminorum</i> .	Just N. of ι <i>Geminorum</i> .	δ <i>Geminorum</i> .
ϵ <i>Leo Majoris</i> .	" S. of β "	2° S. of <i>Præsepe</i> .
1° N. of γ " "	η <i>Leonis</i> .	1° S. of α <i>Leonis</i> .
3° S. of θ " "	$1\frac{1}{2}^\circ$ N. of σ "	τ "
2° S. of π <i>Virginis</i> .	1° N. of β <i>Virginis</i> .	2° S. of β <i>Virginis</i> .

June 28th—Lat. 14° S.; Long. 177° W.

Apparently clear sky, but as cirrus haze was prevalent during the day, presume it is also about to-night, especially as stars are not very bright. Slight cumulus at times. From 7 to 9 P. M. western cone appeared narrow, with hard

outlines, especially to the southward, and no diffused light was seen. At times it nearly equaled the Galaxy, at times rivaled stars of the third magnitude. Only the concentrated bright central portion was visible. Not visible beyond *Jupiter*. At 10 P.M. the central axis appeared 1° more southerly. The southern boundary then extended nearly to δ *Corvi*, the northern to δ *Virginis*.

At 11:15 P.M. the Moon rose, making cirrus streaks apparent.

June 29th—Lat. 9° S.; Long. 175° W.

Cirrus haze and cumulus, with occasional showers and bright, clear intervals. Light observed from 7 P.M. to midnight. Light was bright, extending to the zenith, but gradually faded as the night progressed, particularly to the northward, thus throwing the line of central axis more southerly. No trace of Light beyond *Jupiter*. Moon rose about midnight. Between 7 and 9 P.M. boundaries were noted as follows:—

NORTHERN.	CENTRAL AXIS.	SOUTHERN.
2° N. of μ <i>Leo Majoris</i> .	From about <i>Præsepe</i> ζ <i>Hydræ</i> .	
Just S. of β " "	Just N. of α <i>Leonis</i> .	4° N. of μ <i>Sextantis</i> .
δ <i>Virginis</i> .	" S. of χ "	Midway $\left\{ \begin{array}{l} \theta \text{ Crateris.} \\ \epsilon \text{ " } \end{array} \right.$
<i>Jupiter</i> .	1° S. of β <i>Virginis</i> .	η <i>Corvi</i> .
	α "	7° S. of α <i>Virginis</i> .

REMARKS—*June 28th, 29th, 30th.*

Thin cirrus haze and streaks prevalent throughout each day, and therefore during the nights. They give the Light a hard, apparently true outline, no diffused light either above cone or on either side being visible. The cone generally appears long and narrow, but by continued watching the utmost extent can be obtained—first one boundary, then the other. At times, as one side may be curtailed more than the other, the line of central axis appears to move about, and the true position is only derived by taking the utmost boundaries derived from time to time. If the cirrus streaks lie east and west, it is very hard indeed to distinguish between them and the actual Light. Cirrus haze is frequently unnoticeable when over the bright center of Light, except as it tends to equalize it into a uniform glow with no

markedly brighter central portion. When haze thinly overspreads the sky, its presence can only be detected by constant careful watching.

August 5th — Lat. 15° N.; Long. $161\frac{1}{2}^{\circ}$ W.

10 P. M. to midnight, the sky was clear, but the western branch of the Light too low for good observations. The Gegenschein was distinctly visible as an oval at right angles to the ecliptic situated around ι , τ , 29 *Capricorni*, and to the N. and S. of this center extending nearly to ν *Aquarii*, θ *Capricorni*, ϵ *Capricorni*. At times it also seemed to include ϵ , κ , δ *Capricorni*, extending nearly to λ *Capricorni*, thus seeming circular, but with a *vacant* center, no light being visible between τ and γ *Capricorni*. It also had faint connecting bands running E. and W. about 4° broad. . . .

August 10th — Lat. $9\frac{1}{2}^{\circ}$ S.; Long. 175° W.

. . . The Gegenschein visible from 8 P. M.; circular, with blank central space as before, but the whole was brighter than of late, and the blank space showed the slightest luminosity (though still darker than the surrounding portions) when overhead at 11 P. M.

The eastern branch was quite distinct at 10 P. M. (the night being magnificently clear); broad, too, and more southerly than of late. It consisted of a bright central portion about 10° broad, inclosed by diffused light. The Gegenschein was part of this bright central portion, surrounded, especially to the southward, by diffused light. The blank central space of the Gegenschein appeared the darkest spot in the Zodiacal Band as the eye traced it from the eastern horizon to the Galaxy. . . .

November 15th — Lat. 11° S.; Long. 169° E.

The Light was very distinct between 4 and 5 A. M., when the sky cleared. Its intensity equaled 6 to 7 in *Gemini*, *Leo*, and *Virgo*, evidently much as would be expected, lying along the usual line of central axis, 22° to 12° broad; so gave all my attention looking out for the *Leonids*. (Another *Leonid* observer asked me the next day, what the "curious white rainbow" was which he had noticed!)

1900. *April 26th* — Lat. $19\frac{3}{4}^{\circ}$ S.; Long. $161\frac{1}{2}^{\circ}$ E.

. . . Between 2 and 2:45 A. M. the sky became very clear, and the eastern Light continually increased in altitude, breadth,

and intensity (= 3 to 6). The Gegenschein became larger and brighter, circling round *89, 85, 86, 94 Virginis*, continuing round 3° E. of λ and 3° S. of α to *89 Virginis*, its center being about 3° S. W. of λ *Virginis*. The western Light also became distinct (intensity = 3), broader, and cone-shaped, continuing till Moon rose at 2:45 A. M.

Remarks on the Light in April, 1900.

During the evening the Galaxy and *Venus* have sadly spoiled observations; but it has seemed as if there were hardly any brighter western cone — the Light appeared uniformly diffused, gradually becoming too faint for observation. However, into *Cancer* it could be traced with a fair amount of certainty, but in *Leo* its outlines have been very uncertain and unreliable, especially the northern. In *Virgo* and *Libra* again, outlines have been more reliable, especially soon after midnight.

The Gegenschein appeared fainter as the month progressed. Each night as the twilight glow subsided, a bright glow extended from near *Orion's* head into *Cetus* on the horizon.

The eastern Light invariably first appeared widely diffused, then gradually the central portion became brighter and formed a bright narrow cone, with apex between γ and η *Capricorni*, though as the steamer came south, the diffused Light on the southern edge of the cone was frequently visible when the northern diffused Light had quite disappeared.

May 23d—Lat. 29° S.; Long. $153\frac{1}{2}^{\circ}$ E. (off Queensland Coast).
Moon's age, 24 days.

Air very clear; all stars very bright and clear. Galaxy = intensity 10.

6:30 P. M.—Galaxy and Zodiacal Light distinctly separated from *Gemini* at the western horizon. Light = Galaxy = 10, in *Gemini* and *Cancer*. Clouds intervene.

7:30 P. M.—Light visible around the sky to *Scorpio*, 10° above eastern horizon. Intensity = 5 in *Gemini* and *Cancer*; 4 in *Leo*; 3 in *Virgo* and *Libra*. *Venus* setting.

8:00 P. M.—Light brighter = Galaxy = 8 in *Gemini*, *Cancer*, and *Leo*; 6 in *Leo* and *Virgo*; 3 to 2 in *Libra*.

During this time in *Leo*, *Cancer*, and *Gemini*, the line of central axis appeared much displaced to the southward. The brighter portion ran along a line *Præsepe*, *Regulus*, *Spica* about 6° broad;

to the northward of this brighter portion there was no diffused light, whereas diffused light extended 10° to 8° along its southern outline. Hence the southerly displacement of the central axis.

July 4th—Lat. $33\frac{1}{2}^{\circ}$ N.; Long. 147° W. Moon's age, 7 days.

Misty night, with frequent breaks of intensely clear sky. Could distinguish twelve stars in the *Pleiades* with the naked eye. (α *Ceti* appears to be as bright as γ *Ceti*.) Galaxy = intensity 9 in *Scorpio*, fading to 0 in *Perseus* and *Taurus*. Zodiacal Light just discernible from 2:00 A. M. At 3:00 A. M. the Light = intensity 6 in *Aries* and *Pisces*. Light extended from *Pleiades* (cloudy below this point) to a few degrees beyond δ *Piscium*, the southern outline being best defined. Very hard to distinguish northern outline N. of *Pleiades* from twilight. No trace of Light in *Aquarius*.

A glow, roughly contained between t , v , λ , ζ *Sagittarii*, may be the Gegenschein or may be due to the Galaxy.

R. M. S. "WARRIMOO," July 6, 1900.

PLANETARY PHENOMENA FOR SEPTEMBER, OCTOBER, NOVEMBER, AND DECEMBER, 1900.

BY MALCOLM MCNEILL.

SEPTEMBER.

The Sun reaches the autumnal equinox September 23d, 4 A. M., P. S. T.

Mercury rises about an hour before the Sun on September 1st, but rapidly approaches superior conjunction, reaching it on September 13th, and becoming an evening star, but does not get far enough away for visibility during the rest of the month.

Venus is a morning star, and rises about three and one half hours before sunrise. It reaches its greatest western elongation, 46° , on the night of September 16-17th. It moves about 30° eastward and 4° southward from *Gemini*, south of *Castor* and *Pollux*, through *Cancer* into *Leo*, and at the end of the month is about 6° west and north of *Regulus*.

Mars rises before 1 A. M. It moves about 18° eastward and 3° southward from *Gemini* into *Cancer*. During the early part

of the month it is in the neighborhood of *Castor and Pollux*, and on September 6th passes 6° south of *Pollux*. It is beginning to draw nearer the Earth, and while still not very conspicuous, it is nearly twice as bright as it was during conjunction in January.

Jupiter is drawing rather close to the Sun, and by the end of the month sets less than three hours after sunset. It is still in the constellation *Scorpio*, and moves about 4° eastward during the month.

Saturn is also in the western sky in the evening, somewhat higher up than *Jupiter*, and remains above the horizon until about 10 P. M. on September 30th. It ceases its westward motion and resumes its eastward motion on September 2d, and by the end of the month it has moved rather less than 1° along a line a little south of the course it pursued while moving westward.

Uranus moves a little less than 1° eastward in the constellation *Scorpio*, not far away from *Jupiter*. *Jupiter's* greater relative motion eastward is bringing the two planets nearer together, and at the end of the month *Uranus* is 2° east and 1° south of *Jupiter*. The planets are, however, so low down after sunset when the stars come out that it will not be an easy matter to see *Uranus* without a telescope.

Neptune is in about the same place on the dividing-line between *Taurus* and *Gemini*.

OCTOBER.

Mercury is an evening star throughout the month, coming to greatest east elongation on October 29th; but on account of the great southern declination of the planet, it remains above the horizon too brief a time after sunset to be visible, except possibly during the last few days of the month when the interval is about an hour.

Venus is a morning star, rising about three and one half hours before sunrise. It has begun to approach the Sun and the distance lessens about 4° during the month. Its motion among the stars is 32° eastward and 11° southward through *Leo* into *Virgo*. On October 7th it passes less than 1° south of *Regulus*, α *Leonis*.

Mars rises before midnight at the end of the month. It moves 17° eastward and 4° southward from *Cancer* into *Leo*, passing very close to the "Beehive" cluster in the former constellation during the first week of the month.

Jupiter is drawing too close to the Sun for the best observation, and by the end of the month sets less than two hours later. It moves about 6° eastward and southward during the month in *Scorpio*. There will be a very close conjunction with the Moon on the evening of October 26th, which will be an occultation west and south of the United States.

Saturn is in the southwestern sky in the evening, following about an hour after *Jupiter*. It is still in *Sagittarius*, north of the principal stars, and moves 2° eastward during the month.

Uranus is too low down after sunset for good observation. It is very near *Jupiter*, and the two planets are in conjunction on October 19th, *Jupiter* being $25'$ north of *Uranus*. On October 26th *Uranus* is occulted by the Moon, the phenomenon taking place shortly after sunset in the eastern part of the United States.

Neptune is nearly stationary.

NOVEMBER.

Eclipse.—There will be an annular eclipse of the Sun on the morning of November 22d, visible only in the southern hemisphere. The path of the annulus begins in the South Atlantic, crosses South Africa and the Indian Ocean, and ends in Australia.

Mercury is an evening star at the beginning of the month, setting a little less than an hour after sunset, then rapidly approaches the Sun, passing inferior conjunction on November 20th, and becoming a morning star. By the end of the month it rises an hour and a half before sunrise, and will be an easy object to see in good weather.

Venus is a morning star, and is drawing nearer the Sun. The interval between its rising and sunrise shortens to about three hours at the end of the month from half an hour greater at the beginning. It moves 33° eastward and 13° southward from one end to the other of *Virgo*. On November 6th it passes $13'$ north of the fourth-magnitude star η *Virginis*.

Mars rises earlier, at about 11 P.M., at the close of the month. It moves 13° eastward and 4° southward through the western part of *Leo*, and on November 18th passes about $1^{\circ} 30'$ north of *Regulus*, a *Leonis*.

Jupiter is drawing too close to the Sun to be conspicuously seen during the latter half of the month, the interval between sunset and its setting being less than an hour at the end. Still it is so bright that it can be seen if one looks sharply.

Saturn is also drawing nearer the Sun, and by the end of the month sets less than two hours after sunset. It moves 3° eastward in the constellation *Sagittarius* a little north of the handle of the "dipper."

Uranus is also in the neighborhood of the Sun, not quite as far to the east as *Jupiter*, and too near to be seen, on account of its faintness.

Neptune is retrograding (moving westward) slowly in the extreme eastern part of *Taurus*.

DECEMBER.

The Sun reaches the solstice, and winter begins December 21st, 10 P.M., P. S. T.

Mercury is a morning star throughout the month, and comes to greatest west elongation on the evening of December 7th. It then rises about an hour and three quarters before sunrise, and until nearly the close of the month the interval is more than an hour. So this is one of the best times of the year for seeing the planet if one is an early riser.

Venus is still a morning star, slowly overtaking the Sun on its eastward journey. The interval between the rising of the planet and the Sun shortens from three to a little more than two hours during the month. The planet moves 38° eastward and 10° southward from the eastern part of *Virgo* through *Libra* into *Scorpio*.

Mars is getting into position for evening observation, rising before 10 P.M. at the end of the month. It is still moving eastward among the stars in *Leo*, and traverses an arc of 8° , but the motion is slowing up, preparatory to the retrograde motion about the time of opposition in 1901. On December 16th it passes only 6' south of the fifth magnitude star ϵ *Leonis*. Its actual distance from the Earth is diminishing, and on December 24th it is the same as the Earth's mean distance from the Sun. Its brightness has also increased, and at the end of December it is about six times as great as it was at the time of conjunction with the Sun in January. It will be much brighter than this at opposition, but is now beginning to be a noteworthy object.

The next three planets all come to conjunction with the Sun during December — *Jupiter* on the 14th, *Saturn* on the 29th, and *Uranus* on the 5th. Consequently, none of them are in good position for observation, and they will not be far enough

away to be conspicuously seen as morning objects until February or March, 1901. There will be an interesting conjunction of *Mercury* and *Jupiter* on the morning of December 30th, *Mercury* being 44' south of *Jupiter*. The latter can probably be seen in the morning twilight, but it is doubtful whether the former can be seen without a telescope.

Neptune is in opposition with the Sun on December 19th.

SEPTEMBER-OCTOBER, 1900.

PHASES OF THE MOON, P. S. T.

First Quarter . . .	Sept. 1,	11 ^h 56 ^m	P. M.
Full Moon . . .	Sept. 8,	9 6	P. M.
Last Quarter . . .	Sept. 15,	12 57	P. M.
New Moon . . .	Sept. 23,	11 57	A. M.
First Quarter . . .	Oct. 1,	11 11	P. M.
Full Moon . . .	Oct. 8,	5 18	A. M.
Last Quarter . . .	Oct. 15,	1 51	A. M.
New Moon . . .	Oct. 23,	5 27	A. M.
First Quarter . . .	Oct. 31,	12 17	A. M.

THE SUN.

	1900.	R. A.	Declination.	Rises.	Transits.	Sets.
Sept.	1,	10 ^h 41 ^m	+ 8° 22'	5 ^h 31 ^m A. M.	noon	6 ^h 29 ^m P. M.
	11,	11 17	+ 4 39	5 42	11 57 A. M.	6 12
	21,	11 53	+ 0 47	5 51	11 53	5 55
Oct.	1,	12 29	— 3 7	6 0	11 50	5 40
	11,	13 5	— 6 57	6 11	11 47	5 23
	21,	13 43	— 10 38	6 21	11 45	5 9
	31,	14 21	— 14 3	6 32	11 44	4 56

MERCURY.

Sept.	1,	9 59	+ 13 56	4 31 A. M.	11 19 A. M.	6 7 P. M.
	11,	11 12	+ 6 59	5 28	11 52	6 16
	21,	12 18	— 0 53	6 21	12 18 P. M.	6 15
Oct.	1,	13 17	— 8 20	7 6	12 38	6 10
	11,	14 13	— 14 49	7 46	12 55	6 4
	21,	15 7	— 19 58	8 20	1 9	5 58
	31,	15 54	— 23 13	8 40	1 16	5 52

VENUS.

Sept.	1,	7 39	+ 17 40	1 58 A. M.	8 59 A. M.	4 0 P. M.
	11,	8 16	+ 16 59	1 57	8 56	3 55
	21,	8 56	+ 15 33	2 2	8 56	3 50
Oct.	1,	9 38	+ 13 20	2 13	8 59	3 45
	11,	10 21	+ 10 23	2 26	9 2	3 38
	21,	11 4	+ 6 50	2 43	9 6	3 29
	31,	11 47	+ 2 48	3 1	9 10	3 19

MARS.

Sept. 1,	7 3	+ 23 15	1 0 A.M.	8 23 A.M.	3 48 P.M.
11,	7 30	+ 22 35	12 49	8 10	3 31
21,	7 56	+ 21 41	12 40	7 57	3 14
Oct. 1,	8 21	+ 20 35	12 30	7 43	2 56
11,	8 45	+ 19 20	12 19	7 27	2 35
21,	9 8	+ 17 59	12 7	7 10	2 13
31,	9 29	+ 16 35	11 54 P.M.	6 52	1 50

JUPITER.

Sept. 1,	16 3	— 20 10	12 34 P.M.	5 22 P.M.	10 10 P.M.
Oct. 1,	16 20	— 20 58	10 55 A.M.	3 40	8 25
Nov. 1,	16 44	— 21 54	9 22	2 3	6 44

SATURN.

Sept. 1,	17 53	— 22 36	2 32 P.M.	7 11 P.M.	11 50 P.M.
Oct. 1,	17 56	— 22 41	12 38	5 16	9 54
Nov. 1,	18 5	— 22 45	10 45 A.M.	3 23	8 1

URANUS.

Sept. 1,	16 27	— 21 43	1 4 P.M.	5 46 P.M.	10 28 P.M.
Oct. 1,	16 30	— 21 50	11 9 A.M.	3 51	8 33
Nov. 1,	16 37	— 22 3	9 14	1 55	6 36

NEPTUNE.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
Sept. 1,	5 ^h 56 ^m	+ 22° 14'	11 ^h 55 ^m P.M.	7 ^h 15 ^m A.M.	2 ^h 35 ^m P.M.
Oct. 1,	5 57	+ 22 13	9 59	5 19	12 39
Nov. 1,	5 56	+ 22 12	7 56	3 16	10 36 A.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R,	Sept. 1,	10 ^h 19 ^m P.M.	I, R,	Oct. 3,	6 ^h 54 ^m P.M.
I, R,	3,	4 46	I, R,	19,	5 12
II, D,	3,	4 52	I, R,	26,	7 7
II, R,	3,	7 21	II, R,	30,	4 21
I, R,	10,	6 41			
II, D,	10,	7 30			
II, R,	10,	10 0			
I, R,	17,	8 35			
III, R,	23,	4 50			
I, R,	26,	5 0			
II, R,	28,	4 34			
III, D,	30,	6 44			

NOVEMBER-DECEMBER, 1900.

PHASES OF THE MOON, P. S. T.

Full Moon	Nov. 6,	3 ^h 0 ^m	P. M.
Last Quarter	Nov. 13,	6 37	P. M.
New Moon	Nov. 21,	11 17	P. M.
First Quarter	Nov. 29,	9 35	A. M.
Full Moon	Dec. 6,	2 38	A. M.
Last Quarter	Dec. 13,	2 42	P. M.
New Moon	Dec. 21,	4 1	P. M.
First Quarter	Dec. 28,	5 48	P. M.

THE SUN.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
Nov. 1,	14 ^h 25 ^m	— 14° 23'	6 ^h 34 ^m A. M.	11 ^h 44 ^m A. M.	4 ^h 54 ^m P. M.
11,	15 5	— 17 23	6 45	11 44	4 43
21,	15 46	— 19 53	6 57	11 46	4 35
Dec. 1,	16 29	— 21 47	7 5	11 49	4 29
11,	17 12	— 23 0	7 16	11 53	4 30
21,	17 57	— 23 27	7 23	11 58	4 33
31,	18 41	— 23 7	7 26	12 3	4 40

MERCURY.

Nov. 1,	15 57	— 23 24	8 41 A. M.	1 16 P. M.	5 51 P. M.
11,	16 15	— 23 21	8 18	12 54	5 29
21,	15 37	— 18 29	6 42	11 37 A. M.	4 32
Dec. 1,	15 14	— 15 18	5 28	10 35	3 42
11,	15 47	— 17 56	5 31	10 28	3 25
21,	16 43	— 21 33	6 1	10 44	3 27
31,	17 47	— 23 55	6 37	11 00	3 41

VENUS.

Nov. 1,	11 52	+ 2 22	3 3 A. M.	9 11 A. M.	3 19 P. M.
11,	12 36	— 1 59	3 22	9 15	3 8
21,	13 21	— 6 25	3 42	9 20	2 58
Dec. 1,	14 6	— 10 43	4 4	9 27	2 50
11,	14 54	— 14 41	4 26	9 35	2 44
21,	15 43	— 18 5	4 48	9 45	2 42
31,	16 35	— 20 42	5 11	9 57	2 43

MARS.

Nov. 1,	9 31	+ 16 26	11 53 P. M.	6 50 A. M.	1 47 P. M.
11,	9 50	+ 15 2	11 38	6 30	1 22
21,	10 8	+ 13 41	11 22	6 9	12 56
Dec. 1,	10 24	+ 12 28	11 2	5 45	12 28
11,	10 38	+ 11 25	10 41	5 20	11 59 A. M.
21,	10 49	+ 10 38	10 16	4 52	11 28
21,	10 57	+ 10 11	9 45	4 20	10 55

JUPITER.

Nov.	1,	16	44	— 21	54	9 22 A.M.	2 3 P.M.	6 44 P.M.
Dec.	1,	17	12	— 22	39	7 54	12 33	5 12
Jan.	1,	17	43	— 23	5	6 24	11 1 A.M.	3 38

SATURN.

Nov.	1,	18	5	— 22	45	10 45 A.M.	3 23 P.M.	8 1 P.M.
Dec.	1,	18	18	— 22	45	9 0	1 38	6 16
Jan.	1,	18	34	— 22	37	7 14	11 52 A.M.	4 30

URANUS.

Nov.	1,	16	37	— 22	3	9 14 A.M.	1 55 P.M.	6 36 P.M.
Dec.	1,	16	44	— 22	17	7 24	12 4	4 44
Jan.	1,	16	52	— 22	31	5 32	10 11 A.M.	2 50

NEPTUNE.

Nov.	1,	5	56	+ 22	12	7 56 P.M.	3 16 A.M.	10 36 A.M.
Dec.	1,	5	53	+ 22	11	5 51	1 11	8 31
Jan.	1,	5	49	+ 22	11	3 46	11 6 P.M.	6 26

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R, Nov.	4,	3 ^h 30 ^m P.M.	III, R, Nov.	5,	4 ^h 51 ^m P.M.
III, D,	5,	2 38 P.M.	I, R,	11,	5 25 P.M.

No eclipses visible this year after November 11th, *Jupiter* being too near the Sun.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

It has seemed appropriate to supplement the account of the life-work of Professor KEELER, which Professor CAMPBELL has written for the Society, with a more extended account of the scientific investigations which claimed his attention during the two years of his Directorship of the Lick Observatory, especially as we have such an account from his own pen—the last article written by him. We therefore reprint in this number the article on “The Crossley Reflector of the Lick Observatory,” which Professor KEELER contributed to the June (1900) number of the *Astrophysical Journal*.

VENUS BY DAYLIGHT.

In his notes on Planetary Phenomena in No. 73 of these *Publications*, Professor MCNEILL called attention to the fact that *Venus* could readily be seen in full daylight in clear weather throughout the month of May of this year. It may be of interest to note that the planet was seen here without difficulty whenever it was looked for by daylight in the months of March, April, and June, as well as May.

Venus came to inferior conjunction with the Sun on July 7th, and I was interested to see how near this date it could be seen by daylight without telescopic aid. On June 29th, at 3 P.M., I found it clearly visible to the naked eye without the aid of a “pointer.” On July 2d, at 12:30 P.M., it was seen with the greatest difficulty, and only by using the telescope tube as a “pointer.” On July 5th, at 10:30 A.M., the 12-inch telescope was turned on the planet, the object-glass being screened as far as possible from direct sunlight. *Venus* appeared as an exceedingly narrow crescent that could be traced through fully 180° . At its widest part, the width of the crescent was estimated at less

*Lick Astronomical Department of the University of California.

than one second of arc. After passing the Sun, the planet was not looked for by daylight until August 22d, at 10 A.M., when it was, of course, very easily seen. R. G. AITKEN.

DISCOVERY OF THREE HUNDRED DOUBLE STARS.

During the years 1898-99, I was engaged in remeasuring all the double stars discovered at Pulkowa, principally from 1841 to 1843, by OTTO STRUVE. In the course of this work I discovered new companions to a few of these stars. I also frequently measured other pairs which happened to be in the vicinity of those found by OTTO STRUVE, and some of these miscellaneous pairs have proved to be new.

When the work on the Pulkowa stars drew towards a close, so that considerable gaps existed in my programme, I began to examine large numbers of stars in various parts of the sky, particularly towards the south, in the hope of discovering new pairs. This work has now been carried on systematically for about fourteen months, resulting in the discovery of three hundred new double stars, having distances under five seconds of arc.

Sets of measures of these stars have been obtained as speedily as circumstances have permitted. Observations of one hundred pairs were printed in the *Astronomical Journal*, No. 480, and observations of a second hundred have been forwarded to the same periodical for publication. Sets of measures of the third hundred have not yet been completed, though most of them have been observed on at least one night.

With respect to the distances between their components, these new pairs have the following classification:

0".25 or less,	18 pairs.
0.26 to 0".50,	41 "
0.51 to 1.00,	63 "
1.01 to 2.00,	80 "
2.01 to 5.00,	98 "
	300

Many of these stars are difficult to measure, either on account of the closeness of their components or the faintness of their companions. On this account I have generally observed them with the 36-inch telescope. Some of the close pairs, even some of those whose distances do not exceed 0".25, have been discov-

ered with the 12-inch telescope. But measures of such pairs have not been made with this instrument.

It would have been an easy matter to have increased the number of discoveries considerably by including pairs having distances somewhat greater than 5". This, however, has not seemed desirable, and only a few such pairs have been measured, and the results for one only published. W. J. HUSSEY.

September 18, 1900.

ELLIPTIC ELEMENTS OF COMET 1896 V, GIACOBINI.

In November, 1896, I computed elements of the orbit of this comet from places corresponding to the dates 1896, September 8th, October 5th and 29th. The elements then obtained did not accurately represent the observed path of the comet during the latter part of its apparition. About a year ago I found the origin of the discrepancy in a slightly erroneous position of the comparison-star used for the last observation, and at that time computed the system of elements given below. These elements are based on normal places having the dates 1896, September 8th, October 29th, and 1897, January 4th. The interval included between the extreme dates is only four days less than the apparition period of the comet.

Epoch 1896 November 1.5 G. M. T.

$$\begin{array}{rcl} M = & 0^{\circ} & 39' \ 56''.5 \\ \Omega = & 193 & 28 \ 47.4 \\ i = & 11 & 21 \ 14.7 \\ \omega = & 140 & 33 \ 43.4 \\ \phi = & 35 & 42 \ 7.6 \end{array} \left. \vphantom{\begin{array}{rcl} M = \\ \Omega = \\ i = \\ \omega = \\ \phi = \end{array}} \right\} 1896.0$$

$$\log e = 9.766094$$

$$\log a = 0.542898$$

$$\mu = 544''.0765$$

$$\text{Period} = 6.52 \text{ years.}$$

W. J. HUSSEY.

PROPER MOTION OF Ω 165, 45 GEMINORUM.

OTTO STRUVE discovered a faint companion of 45 Geminorum about 1842, and first measured its position in 1847. Misled by erroneous observations made in 1877, he thought that the change in the relative positions of the two stars was due to orbital motion. This, however, is not the case. It results entirely from the proper motion of the principal star. This is clearly estab-

lished by comparing the proper motion of the principal star as derived from the micrometrical measures with that furnished by the meridian observations. I have obtained the following results from the measures of position-angle and distance:—

$$\mu = - 0''.00046, \quad \mu' = - 0''.1058,$$

while those given by Professor NEWCOMB in his "Catalogue of Fundamental Stars," derived from the meridian observations of the principal star, are:—

$$\mu = - 0''.00075, \quad \mu' = - 0''.1090.$$

These results are in substantial agreement; their differences may be attributed entirely to errors of observation.

W. J. HUSSEY.

VISUAL EXAMINATION OF *CAPELLA*.

[Reprinted from *Astronomical Journal*, No. —.]

Some months ago Professor CAMPBELL discovered that *Capella* is a spectroscopic binary having a period of 104 days. From the spectroscopic observations it is known that the orbit is nearly circular, and that the components are not very unequal in brightness. The variations of the velocities of the components in the line of sight furnish the minimum dimensions of the orbit. A combination of these dimensions with ELKIN's parallax gives a result from which it appeared not impossible that *Capella* might at times be seen as a visual double star, thus forming a connecting link between the visual and spectroscopic binaries. The recent most favorable dates for the examination of the star to this end were April 15th, June 6th, and July 28th. At these times the apparent distance between the components would be a maximum. On account of the orbit's being nearly circular the apparent distance has nearly its maximum value for a few days on either side of the dates given.

Early in June I examined *Capella* on several afternoons with the 36-inch telescope without obtaining any visual evidence of its being a double star. The results then obtained, however, were not regarded as conclusive; for the seeing, though good, was not such as to be rated as excellent according to our standards. These examinations were made when the star was from three to four hours west of the meridian.

On the nights of August 2d and 5th I made further examinations with the same telescope, using powers 1000, 1500, 1900,

and 2600. With all powers the star appeared round. On these dates the seeing was excellent and stood all these powers perfectly. On the last date the seeing was perhaps the best. Even at Mt. Hamilton we have few nights that are better in the course of a year. With such conditions as then prevailed an elongation of a tenth of a second would have been readily perceptible with the lowest power used, and a considerably smaller distance would have been noted with the higher ones. At the times of these observations the star was between three and four hours east of the meridian. On August 5th color-screens of various shades were used a part of the time to reduce the light. On this date Mr. PERRINE was with me. He also made a very careful examination of the star with all powers, without detecting any elongation.

W. J. HUSSEY.

MT. HAMILTON, Aug. 10, 1900.

NOTE ON *CAPELLA* AS A DOUBLE STAR.

The elements deduced from the spectroscopic observations of this binary system indicated the possibility that the two components might be sufficiently separated to be seen directly with the 36-inch refractor. The star was therefore examined with that instrument under good conditions on the evenings of February 24th, and April 16th, and on the mornings of July 22d, July 29th, and August 11th. Once or twice, especially on the first night, a slight elongation was suspected, but settings with the micrometer ranged over 60° , showing that no real elongation was observed. On the morning of July 29th, the seeing was very good; several very difficult stars were measured shortly before turning to *Capella*; and the latter star was followed for over an hour, using eye-pieces of all powers to 2600, with and without shades of red and orange glass, but no certain elongation could be detected. The spectroscopic observations show that the separation of the two components was a maximum on the dates February 22d, April 15th, and July 28-29th.

R. G. AITKEN.

September, 1900.

THE TRIPLE STAR κ *PEGASI*.

The visual double star having the shortest known period of revolution is the fourth-magnitude star κ *Pegasi*. It was discovered by BURNHAM in 1880 with the $18\frac{1}{2}$ -inch telescope, and

is one of the very difficult stars on his list. The approximate magnitudes of the two components are $4\frac{1}{2}$ and 5. The major semi-axis of the relative elliptic orbit of one around the other is $0''.4$, and the period of revolution is a little over eleven years. The present distance between the components is less than $0''.2$, in position-angle 260° .

One of the components — probably the component whose spectrum is the stronger in the blue region — is a spectroscopic binary. κ *Pegasi* is therefore a triple star of more than usual interest. The shifting of the lines in the spectrum, as observed with the Mills spectrograph, have furnished the following velocities of one component, with reference to the solar system:

DATES.	VELOCITY.
1896, Aug. 31	— 43^{km}
1899, July 17	— 41
1900, Aug. 6	+ 35
“ 7	+ 27
“ 8	— 16
“ 12	+ 35
“ 21	— 45
“ 22	— 34

The variation in the velocity was discovered from the third plate. The period of rotation of the bright component around an invisible companion is about six days.

Changes in the appearance of the spectrum have been noted, but I have not yet determined their nature.

On account of the closeness of the two visual components, it is impossible to secure their spectra separately; and for this reason I am not able to state which visual component is the spectroscopic binary.

W. W. CAMPBELL.

A NEW PLANETARY NEBULA.

While examining Comet *b* 1900 (BORRELLY-BROOKS) with the 12-inch telescope on the evening of August 31st, I found D.M. $+83^\circ 357$ (9.4^{m}) to be a small nebula instead of a star. An examination with the 36-inch telescope on the following night showed that the object was a nebulous star or very small planetary nebula. The nucleus is stellar, of about $10\frac{1}{2}$ to 11 magnitude, and is centrally placed in a round nebulous envelope which is between $5''$ and $6''$ in diameter. The nebula as a whole is about as bright as a 9.5 magnitude star. A 13-magnitude star precedes $14.8''$ in 263° . The position of the nebula for 1855.0 is $12^{\text{h}} 29^{\text{m}} 10^{\text{s}}$, $+83^\circ 21.8''$ (B. B. VI.).

R. G. AITKEN.

COMET *b*, 1900 (BORRELLY-BROOKS).

This comet was discovered by BORRELLY at Marseilles on the 23d of July, and independently the same night by BROOKS at Geneva, N. Y. It was observed here on the 24th, when it appeared as a very beautiful object. At that time the nucleus gave evidence of being double, and was of the $6\frac{1}{2}$ magnitude. The following night the nucleus and whole head appeared perceptibly fainter. The nucleus no longer appeared double, but was elongated in the direction of the axis of the tail. Mr. PALMER photographed this comet on the night of the 25th. An exposure of one hour and a half shows a little over six degrees of tail. Two photographs taken the next night, one by Mr. PALMER, the other by myself, show only about one degree of tail. These exposures were for two hours.

According to elements by Mr. PERRINE, the comet passed perihelion on the 3d of August. An observation was made on the 11th of August, at which time the nucleus was sharp, round, and of the 11th magnitude, the magnitude of the whole head being $9\frac{1}{2}$.

R. T. CRAWFORD.

ELEMENTS OF COMET *b*, 1900 (BORRELLY-BROOKS).

From Mr. CRAWFORD's observation of July 25th, and my own of July 30th and August 4th, I find the following parabolic elements:—

$$T = 1900 \text{ August } 3.20726 \text{ G. M. T.}$$

$$\begin{array}{rcl} \omega = 12^{\circ} & 26' & 13''.2 \\ \Omega = 328 & 0 & 30.1 \\ i = 62 & 30 & 46.3 \end{array} \left. \vphantom{\begin{array}{l} \omega \\ \Omega \\ i \end{array}} \right\} 1900.0$$

$$\log q = 0.006390$$

Residuals: Observed – Computed.

$$\begin{array}{rcl} \Delta \lambda' \cos \beta' & & + 4''.4 \\ \Delta \beta' & & - 0.9 \end{array}$$

C. D. PERRINE.

Mt. HAMILTON, Cal., Sept. 13, 1900.

HONOR FOR PROFESSOR CAMPBELL.

At the annual commencement on June 14, 1900, the Western University of Pennsylvania conferred the degree of Doctor of Science upon Professor W. W. CAMPBELL, senior astronomer in the Lick Observatory.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., July 10, 1900.

To Professor JAMES E. KEELER, (Received 4:30 P.M.)
Lick Observatory.

A new star has been found by Mrs. FLEMING. Position for 1900.0, $19^{\text{h}} 15^{\text{m}} 16^{\text{s}}$, Decl. $- 0^{\circ} 19'$. In April, 1899, it was of the 8th magnitude, now it is a nebula of the 12th magnitude. We have 16 photographs. (Signed) E. C. PICKERING.

To Lick Observatory, BOSTON, MASS., July 24, 1900.
Mt. Hamilton, Cal. (Received 7:15 P.M.)

A bright comet was found by Dr. W. R. BROOKS [Geneva, N. Y.,] on July 23.750, Greenwich, M. T., in R. A., $2^{\text{h}} 43^{\text{m}}.6$, Decl. $+ 12^{\circ} 30'$. Its motion is northerly. It has a nucleus and a tail. (Signed) JOHN RITCHIE.

CAMBRIDGE, MASS., July 24, 1900.
(Received 7:15 P.M.)

Kiel cables for Lick Observatory the following ephemeris of the periodic Comet De Vico-Swift, computed by F. H. SEARES.* Please look for the comet, and telegraph any observations.

(Signed) E. C. PICKERING.

Lick Observatory, August 8, 1900.

To Harvard College Observatory: (Sent 9:20 A.M.)

The following elements and ephemeris† of Comet *b* 1900 (BORRELLY-BROOKS) were computed by C. D. PERRINE from observations of July 25th, 30th, and August 4th:—

$$\begin{array}{l} T = G. M. T. \text{ August } 3.21. \\ \left. \begin{array}{l} \omega = 12^{\circ} 26' \\ \Omega = 328 \quad 1 \\ \iota = 62 \quad 31 \end{array} \right\} \\ \text{Natural } q = 1.0148. \end{array}$$

(Signed) JAMES E. KEELER,
Per W. W. CAMPBELL.

RESIGNATION OF MR. CODDINGTON AS FELLOW AT THE
LICK OBSERVATORY.

Mr. E. F. CODDINGTON, Fellow in Astronomy at the Lick Observatory during the years 1897–1900, resigned his Fellow-

* The ephemeris for four-day intervals, from July 23d to August 4th, is here omitted.

† The ephemeris at four-day intervals, from August 10th to August 22d, is here omitted.

ship in June, to take effect August 1st. It is Mr. CODDINGTON's purpose to devote one or two years to the further study of theoretical astronomy and related subjects, in some of the European universities.

It is a pleasure to say that Mr. CODDINGTON's services to the Lick Observatory during his three years' residence are highly appreciated by every member of the staff, and that he carried with him our best wishes for his future career. W. W. C.

APPOINTMENT OF FELLOW AT THE LICK OBSERVATORY.

The Regents of the University of California have appointed Dr. HERBERT MEREDITH REESE to the position of Fellow in Astronomy at the Lick Observatory, for the year beginning October 1st. Dr. REESE is an alumnus of Johns Hopkins University, having received there the degrees A. B. in 1897 and Ph. D. in 1900. He held University Scholarships for three years, and last year was a Fellow in Physics.

During the past three years Dr. REESE has been engaged, in the Johns Hopkins Physical Laboratory, in an investigation of the "Zeeman Effect," with reference to the principal chemical elements; i. e. the effect of a magnetic field upon the character of the lines in the spectra of the elements.

Dr. REESE was an assistant to the U. S. Naval Observatory Expedition which observed the total solar eclipse of May 28, 1900, at Pinehurst, N. C. W. W. C.

APPOINTMENT OF ACTING DIRECTOR OF THE LICK OBSERVATORY.

The Regents of the University of California, at a meeting held on September 12th, appointed Astronomer W. W. CAMPBELL to the position of Acting Director of the Lick Observatory, to serve until such time as a new director is elected and assumes the duties of his office.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

The Grand Prize of the Paris Exposition has been awarded to Professor A. MICHELSON, of the University of Chicago, for his Echelon spectroscope.

The honorary degree of Doctor of Science was conferred upon Professor ARMIN O. LEUSCHNER, head of the Department of Astronomy at Berkeley, by the Western University of Pennsylvania at the last annual commencement — June 14, 1900.

The Queen Regent of Spain has signed a decree establishing the method of accounting time in the kingdom as follows:—

(1) In all railway, mail (including telegraph), telephone, and steamship service in the Peninsula and the Balearic Islands, and in all the ministerial offices, the courts, and all public works, time shall be regulated by the time of the Greenwich Observatory, commonly known as western European time.

(2) The computation of the hours in the above-mentioned services will be made from the hour of midnight to the following midnight in hours from 1 to 24, omitting the words *tarde* (afternoon) and *noche* (night), heretofore in customary use.

(3) The hour of midnight will be designated as 24.

(4) The interval, for instance, between midnight (24) and 1 o'clock will be designated as 0.05, 0.10, 0.59. —*Science*.

Spain is thus the first nation in the world to adopt the astronomical, or 24-hour, method in the reckoning of civil time.

Observations of *Capella* as a double star have been made at Greenwich by no less than ten different observers. The observers state that "the change of position-angle observed through a large arc of the orbit agrees on the whole well with the calculated change, taking the period as 104 days." So far as we know, these results have not been confirmed by observations elsewhere.

Science (August 31, 1900) states that the degree of Doctor of Philosophy has been conferred this year on 233 candidates by twenty-two universities in the United States. In 1899 the number was 224, and in 1898, 234. Making a somewhat arbitrary distinc-

tion between the humanities and the sciences, there would seem to be very little difference in the numbers of students in the two classes; for the degree has been conferred in the sciences 105, 115, and 113 times; in the humanities 129, 109, 120 times.

The distribution of students among the different sciences shows that chemistry offers the greatest attraction, and meteorology the least, 85 degrees having been granted in the one, and 1 in the other in the three years.

Nine doctorates have been granted to candidates offering astronomy as their major. We give herewith the names of the four receiving the degree this year and the titles of their theses:

G. N. BAUER: The Parallax of μ *Cassiopeia* and the Positions of 56 Neighboring Stars as Determined from the Rutherford Photographic Measures. Columbia University.

CAROLINE E. FURNESS: Catalogue of Stars within One Degree of the North Pole, and Optical Distortion of the Helsingfors Astrophotographic Telescope, deduced from Photographic Measures. Columbia University.

F. R. MOULTON: A Particular Class of Periodic Solutions of the Problem of Three Bodies. University of Chicago.

H. N. RUSSELL: The General Perturbations of the Major Axis of *Eros* caused by the Action of *Mars*; with the Corresponding Terms in the Mean Longitude. Princeton University.

The second annual meeting of the Astronomical and Astrophysical Society of America was held on June 26–28, 1900, at Columbia University, in connection with the forty-ninth annual meeting of the American Association for the Advancement of Science.

The Secretary's report of the action of the Council showed an increase of forty-three in the membership of the Society during the year. Officers for the year 1900–01 were elected as follows: President, SIMON NEWCOMB; Vice-Presidents, C. A. YOUNG and G. E. HALE; Secretary, G. C. COMSTOCK; Treasurer, C. L. DOOLITTLE; Councillors, E. C. PICKERING, J. E. KEELER, ORMOND STONE and S. J. BROWN.

It was voted to hold the next meeting of the Society in Denver, Colo., in August, 1901.

About forty papers were read at the joint sessions of the Society with Section A of the A. A. A. S., and in addition the observations of the total solar eclipse of May 28, 1900, and the programme to be followed in observing *Eros* for parallax

at the approaching opposition were discussed at length. A general account of these discussions with abstracts of the papers presented before the Society is given by the Secretary, Professor COMSTOCK, in *Science*, Nos. 291 and 292.

In addition to the general accounts of the two expeditions sent from California to observe the Total Eclipse of the Sun last May (which are printed elsewhere in this number), it should be said that nearly all the parties, both in this country and in Europe, were quite successful, especially in the photographic observations. The spectroscopic and spectrographic results are more disappointing, and a number of parties report complete failures in these respects.

Extensive preliminary reports from most of the American parties are printed in the *Astrophysical Journal* for July, 1900. Considerable interest attaches to the results obtained with the bolometer, by members of the Smithsonian Institution party. These are summarized by Professor C. G. ABBOT, in the following statements:—

“1. The coronal radiation was recognized by the bolometer, and gave at least 5^{mm} deflection over that of the dark Moon.

“2. The radiation reflected by the Earth's atmosphere during the partial phase is vastly more intense than that of the corona.

“3. *The corona is effectively cooler than the bolometer, and appears, therefore, neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature, or at least with the preponderance of infra-red rays usual in the spectra of hot bodies.*

“As the last statement,” adds Dr. ABBOT, “involves a rejection of both the eruptive and meteoric coronal theories, it ought to receive searching criticism, and the experimental observations on which it rests ought to be verified at future eclipses.”

Professor T. C. CHAMBERLIN and Dr. F. R. MOULTON have recently been attempting to test the Nebular Hypothesis as formulated by LAPLACE (1) by means of the modern kinetic theory of gases, (2) by a comparison of the moment of momentum of the supposed nebular system with the moment of

momentum of the actual system, and (3) by a study of the ratios of masses to momenta. In *Science* (August 10, 1900), the authors give an interesting abstract of three of their recent technical papers. Without attempting to summarize their argument, we may state that their conclusion is altogether adverse to the tenability of the hypothesis. An original spheroidal nebulous or meteoroidal form of any kind is incompatible with the present distribution of the masses and momenta in the system. In any attempt to construct a tenable hypothesis, "the matter of the system must be so brought together as to give low mass, high momentum, and irregular distribution to the outer part, and high mass, low momentum, and sphericity to the central part." With reference to such an hypothesis, two suggestions are offered (both purely as conjectures) namely, that the system may have been originated by the peripheral collision of a very small nebula upon a large one; or that its primitive form may have been that of a spiral nebula.

Under the auspices of the International Astrophotographic Conference an extensive plan of campaign has been outlined for the determination of the solar parallax from observations of the minor planet *Eros* at its approaching opposition.

It will be remembered that *Eros* at certain oppositions approaches the Earth far more nearly than any other member of the solar system except the Moon, and that this year's opposition is more favorable than any other until the one of 1931. (See these *Publications*, No. 66, pp. 40-44.)

The Conference at its session in Paris, July 19-25, 1900, therefore adopted resolutions declaring it to be desirable that micrometric, heliometric, and photographic observations of *Eros* should be made for the purpose of determining the parallax constant, (a) by combining the morning and evening observations at the same observatory, (b) by combining the observations made at approximately the same absolute time in Europe and North America, and (c) by combining the (nearly) simultaneous observations made at northern and southern observatories. A great deal of work in addition to the actual parallax observations is necessary to insure the highest degree of accuracy. All the stars along the trajectory of the asteroid during the period of observation are to be photographed to afford means of determining with precision the places of the faint stars that must

necessarily be used in the micrometer observations. To give reference points for measuring these plates, 319 of the brighter stars must be observed with the meridian circle at a number of observatories. To eliminate the uncertainty still existing in our knowledge of the motion of *Eros*, various precautions must be taken in combining the observations, and an independent series of observations, both micrometric and photographic, should be available for perfecting the theory of the motion. M. ANDRÉ and M. PROSPER HENRY will also undertake special researches upon the atmospheric dispersion.

As more than thirty different observatories have agreed to co-operate in this work, we may confidently expect a very accurate determination of this fundamental constant of astronomy.

A committee appointed by First Vice-President BURCKHALTER, consisting of Messrs. LOWDEN, PARDEE and CUSHING presented the following resolutions on behalf of the members of the Astronomical Society of the Pacific:—

In Memoriam.

WHEREAS, Professor JAMES EDWARD KEELER, Director of the LICK OBSERVATORY at Mount Hamilton, and President of this Society, died on the twelfth day of August, 1900; and

WHEREAS, The Members of this Society regard this as an appropriate time to express their appreciation of the life and services to science of one who in life sought the praise of none; now therefore, be it

Resolved, That in Professor KEELER we recognize an American citizen of the best type, a man of broad culture, and high scientific attainments, whose reputation as a skilled astronomer was world-wide, and who, by his patient work and consummate ability, aided much in acquiring and maintaining a high standing in the scientific world for the many institutions with which he was connected during his active life.

Resolved, That while by the death of this distinguished scholar Astronomical Science has suffered a great loss, this Society in particular has been deprived of one who has been connected with it from its incorporation, and who, whether in the capacity of Member, Director, or President, has at all times accorded to this Society his unqualified support, and materially assisted in giving it a standing among like Societies throughout the world.

Resolved, In token of our appreciation of Professor KEELER's efforts in behalf of this Society and of our love for him, that these resolutions be spread in full on our minutes, and that a copy thereof be sent with our heartfelt sympathy to the bereaved family.

SAN FRANCISCO, September 22, 1900.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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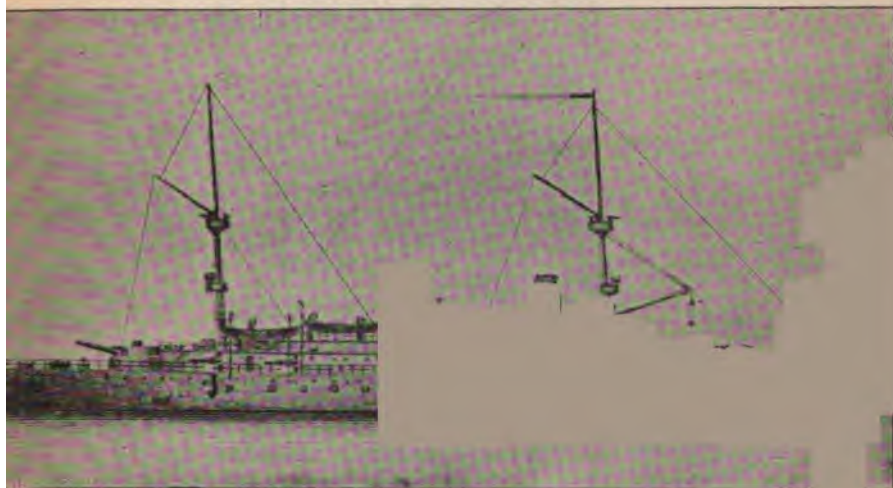
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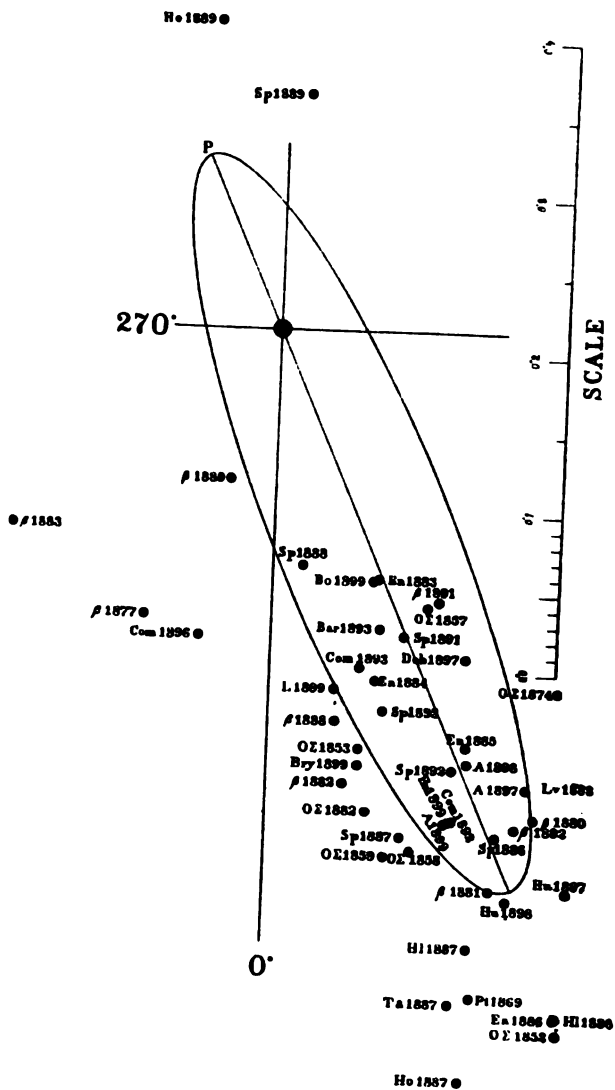
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THE ORBIT OF δ EQUULEI, OΣ 535.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, DECEMBER 1, 1900. No. 76.

TRIAL ELEMENTS OF THE ORBIT OF δ EQUULEI,
OZ 535.

BY WILLIAM J. HUSSEY.

The periodic time of this binary, according to the elements which I have obtained, is 5.7 years. This is only a little more than half of the period of κ Pegasi, whose time of revolution according to BURNHAM's elements is 11.37 years, and which has hitherto been accepted* as the shortest known among the visual double stars.

My elements of δ Equulei are to be regarded as tentative — to be accepted if they represent the motion in the future, to be rejected if they fail in this respect. They have been obtained in the course of an investigation which has had for its object the explanation of the very rapid change in the relative positions of the components of this pair during the past fifteen months. In the summer of 1899 this star was measured with comparative ease with the great telescope. The distance was then fully three tenths of a second. Early in September, 1900, Professor AITKEN called my attention to the fact that it had become an exceedingly difficult pair. It is now too close for exact measurement. We have each examined it on a number of nights recently with the 36-inch telescope when the atmospheric conditions were favorable, and have found it either apparently round or so slightly elongated as to render the results of attempts to measure the

* In 1897, SEE published elements of β 883, with a period of 5.5 years. In Volume I of the *Publications of the Yerkes Observatory*, Professor BURNHAM states that from a careful consideration of all the measures of this star, it is practically certain that the period of five and one half years is not correct, and that it is probable that the period will not be far from that of GLASENAPP, which is 16.35 years. LEWIS, using observations from 1879 to 1900, inclusive, obtains elements with a period of 15.8 years.

Professor AITKEN has followed this star very closely during the past five years, measuring it at short intervals to obtain as nearly as possible a continuous series of observations. His results indicate a much longer period than five and one half years.

direction of elongation very uncertain. According to the elements of its orbit heretofore published, the apparent distance should now be somewhat more than a quarter of a second. As a matter of fact, it is less than one tenth of a second.

This close pair was discovered and first measured by OTTO STRUVE in 1852. Soon thereafter it was ascertained that its motion is rapid; but it was not until 1880 that sets of measures began to be obtained with that regularity and continuity which are necessary to furnish the data for a reliable determination of its orbit. From his own observations, OTTO STRUVE thought the periodic time was either about thirteen years or half of this amount. He was inclined to accept the latter as the more probable.

After the publication of the sets of measures by BURNHAM for the years 1880 to 1883, inclusive, WROUBLEWSKY made the first determination of the elements of the orbit, obtaining a period of 11.478 years. His results were published in 1887. In 1895, when the available data for such an investigation had increased considerably, SEE derived elements which in their essential features are practically the same as those obtained by WROUBLEWSKY. These were slightly modified when reprinted the next year in his *Evolution of Stellar Systems*. Their results are as follows:—

	WROUBLEWSKY.	SEE (1895).	SEE (1896.)
Period =	11.478 years.	11.45 years.	11.45 years.
T =	1892.03	1892.80	1892.80
$\Omega =$	24°.05	22°.2	22°.2
$\lambda = \pi - \Omega =$	26°.61	0°.00	0°.0
$i =$	81°.75	79°.05	79°.0
$e =$	0.2011	0.14	0.165
$a =$	0".406	0".452	0".452

The components of δ Equulei do not differ much in brightness. In the years 1897, 1898, and 1899, I measured this star thirteen times. On two nights I thought the companion was in the third quadrant, on eight in the first quadrant, and on three I was in doubt. Whenever the atmospheric conditions are unfavorable, it is difficult to determine the quadrant of this pair with certainty. In this respect the published observations present numerous discordances, and in some instances observers appear to have been guided by WROUBLEWSKY'S elements in fixing the quadrant rather than by their

own independent examinations. On account of these discrepancies, it is necessary to alter the position-angles of some of the observations by 180° , in order to arrange the data for a determination of the elements of the orbit.

When the observations are arranged to correspond to a period of nearly eleven and one half years and then plotted, nearly all the points representing them fall into one or the other of two groups, situated upon opposite sides of the origin, in approximately the directions 20° and 200° . On one side the observations are somewhat more numerous than on the other, and the extreme distances there are a little greater. When one attempts to draw an apparent ellipse guided by the consideration that the areas described by the apparent distance vary proportionally to the times of their description, it is found that the observations can be satisfied only by making the apparent ellipse such that the true orbit is nearly circular. It will be noticed that the eccentricity, as given by WROUBLEWSKY and by SEE, is very much smaller than is usually found in double-star orbits.

I computed a system of elements for δ *Equulei* in accordance with the hypothesis that the period is about eleven and one-half years, and at once obtained a smaller value for the eccentricity than those given above. With these provisional elements, I computed the mean anomalies corresponding to all the observed position-angles which appeared to be reliable, my judgment of their reliability being based upon the results obtained in the course of the measurement of the areas described by the apparent distance. When these mean anomalies were plotted, using the time as the independent variable, it was found that they deviated systematically from a straight line, along which they should lie in accordance with theory. Values corresponding to the observations which had been assumed to belong on one side of the origin were situated above the line that best represented them, taken as a whole, while those on the opposite side of the origin fell below it. I examined the effect which a variation of the several elements would have upon this systematic deviation and concluded that to remove it, it would be necessary further to decrease the eccentricity. By successive steps this was done until the eccentricity had become 0.05, or until the true orbit was assumed to be as nearly circular as that of *Jupiter*. Even then the mean anomalies did not conform to theoretical requirements, and it became apparent that this would not be the case

unless the eccentricity was taken equal to zero, or the true orbit assumed to be a circle. Now, for a circular orbit the center of the apparent ellipse coincides with the origin, and consequently an entire group of observations situated in a given quadrant may be transferred bodily to the opposite quadrant, and there be represented by the same ellipse without disturbing the proportionality of the areas described by the apparent distance to the times of their description.

When I made a comparison of the observations with places computed by means of the elements which I had obtained, taking the eccentricity equal to 0.05, I found the agreement of the results satisfactory for those observations which correspond to points in the vicinity of the vertices of the apparent ellipse; that is, for measures whose position-angles do not differ more than ten or fifteen degrees from 20° and 200° . Some of the other observed angles were also well represented, but there was a notable discrepancy between the observed and computed places for the present time, as is also the case with the published orbits quoted above. Since no system of nearly circular elements can account for the rapid change in distance during the past fifteen months, I at once rearranged the observations to correspond to a period of half the length of that which had previously been assumed, and obtained the elements given below. When the mean anomalies corresponding to the observed position-angles were computed by means of these elements and plotted as before, all evidence of systematic variation disappeared. The values, extending over nearly three thousand degrees of mean anomaly, ranged along a straight line with as much precision as could be expected in a quantity which changes so rapidly, $63^\circ.16$ a year, and which for the directions given by most of the measures is so largely influenced by possible errors of observation.

My elements are as follows:—

$$\begin{aligned}
 \text{Period} &= 5.70 \text{ years.} \\
 T &= 1901.18 \\
 \Omega &= 24^\circ.1 \\
 \lambda &= 179.0 \\
 i &= 74.5 \quad \left. \vphantom{\begin{matrix} \Omega \\ \lambda \\ i \end{matrix}} \right\} 1900. \\
 e &= 0.54 \\
 a &= 0''.25 \\
 &\text{Motion retrograde.}
 \end{aligned}$$

λ is here reckoned in the direction of increasing position-angles, so that when M , E , and v are counted as usual in the direction of motion, we have the following formulas for computing the position-angle and distance:—

$$\begin{aligned}\rho \sin (\theta - \Omega) &= r \sin (-v + \lambda) \cos i, \\ \rho \cos (\theta - \Omega) &= r \cos (-v + \lambda),\end{aligned}$$

v and r being found by the usual equations.

An ephemeris computed by means of these elements for each ten degrees of mean anomaly, or for each thirty-sixth part of a revolution is given below. It is given in this form in order that it may be available for the comparison of the observations of any revolution. About a third of the time, however, the motion is so rapid as to render a comparison with the ephemeris roughly approximate only.

In the table giving the Comparison of Observed and Computed Places, the Computed Places have been interpolated from the ephemeris when the motion is slow, and computed directly for the date of observation when it is rapid. The observed position-angles have been reduced to the epoch 1900 by applying the corrections for precession, except for those values which are given in integers and which are approximate only.

An inspection of the columns of residuals, $O - C$, will show the manner in which these elements represent the observations through no less than eight complete revolutions. While some of the residuals are large, the number of this character is perhaps not greater than is to be expected for a star which has been observed so frequently with instruments of such great variety and which at all times is so difficult. In a considerable number of the cases in which the residuals are abnormally large, the observers have particularly noted that the atmospheric conditions were unfavorable, or that the star for other reasons was difficult to measure. Thus, OTTO STRUVE states that the atmospheric conditions were poor at the time of his observation of 1865.91. WINLOCK and SEARLE regarded their measures of 1866.78 as very unsatisfactory.* ENGELMANN's observations were made with a small telescope, and the difficulty of the star for such an instrument is a sufficient explanation of the magnitude of some of his residuals. HALL's angle of 1879.77 is published as uncer-

* Professor PICKERING has very kindly examined the original records of these observations for me, and states that but little weight should be given to them.

tain, and LEAVENWORTH states the star was exceedingly difficult with his instrument.

From a casual examination of the column of residuals, it might appear that the late measures of angle by Professor AITKEN are not represented as closely as desirable, and on this account that the several elements require considerable corrections. This may or may not be so. If it is, they should be corrected when the data requisite for the purpose become available. Further observations in other parts of the orbit are desirable to fix with greater certainty the geometrical elements. The periodic time and epoch of periastron passage appear to be well determined. Elsewhere in this number of these *Publications*, Professor AITKEN gives the details of his observations. A reference to his paper will show that he regards his measure of 1900 61 as more reliable than those which he obtained later. I have accordingly given it the preference in the final adjustment of the periodic time and epoch of periastron passage. According to these elements, the angular motion was very rapid during the period covered by these measures, a part of the time amounting to nearly a degree a day, and when we consider the present extreme difficulty of the star, the residuals are more consistent than might have been expected from *a priori* considerations. It may further be remarked in this connection, that all of his measures of angle for the year 1900 will give residuals well within reasonable limits for the possible errors of observation by increasing the date of periastron by only one-twentieth of a year, and if at the same time the periodic time be increased by one one-hundredth of a year, the entire series of residuals from 1852 to 1900 will not be materially affected.

According to my elements, the apparent distance of the companion is greater when it is at periastron (at P in the diagram), than it is before and after that epoch. For a brief period about that time the star should appear distinctly elongated when seen under favorable conditions with a large telescope. Half a year earlier or later it should appear nearly or quite round. From this consideration it appears not improbable that the data may be forthcoming within a few months, which will decide whether the short period given by the elements which I have obtained is correct or not.

LICK OBSERVATORY, November 22, 1900.

COMPARISON OF OBSERVED AND COMPUTED PLACES.

DATES.	COMPUTED.		OBSERVED.		O - C.		No. OF NIGHTS	Observers.
	θ	ρ	θ	ρ	$\Delta \theta$	$\Delta \rho$		
	$^{\circ}$	"	$^{\circ}$	"	$^{\circ}$	"		
1852.66	24.3	0.39	22.8	0.48	- 1.5	+0.09	2	OΣ
1853.91	15.3	0.29	12.3	0.27	- 3.0	-0.02	1	OΣ
1854.69	358.0	0.13	Single.		....	....	1	OΣ
1856.57	43.9	0.16	Single.		....	....	1	OΣ
1857.67	28.7	0.35	29.4	0.20±	+ 0.7	-0.15±	2	OΣ
1858.59	22.9	0.38	15.8	0.34±	- 7.1	-0.04±	1	OΣ
1859.65	14.9	0.29	13.0	0.34±	- 1.9	+0.05±	1	OΣ
1861.51	184.5	0.09	236?	....	....	....	1	OΣ
1865.91	5.7	0.18	22.7	<0.5	+ 17.0	....	1	OΣ
1866.78	219.2	0.09	230.3	....	+ 11.1	....	1	Wl
1866.78	219.2	0.09	110.3	....	-108.9	....	1	Sr
1869.69	24.7	0.38	5	....	- 20	....	1	Du
1869.75	24.3	0.39	10.7	....	- 13.6	....	2	Wl
1869.75	24.3	0.39	17.8	0.44	- 6.5	+0.05	4, 1	Pi
1870.73	17.9	0.33	8	....	- 10	....	1	Du
1874.67	29.4	0.34	22.1	....	- 7.3	....	1	OΣ
1874.73	28.8	0.35	359.9	....	- 28.9	....	1	OΣ
1874.75	28.8	0.35	38.9	0.29±	+ 10.1	-0.06±	1	OΣ
1877.76	329.9	0.06	336.3	0.2 ±	+ 6.4	+0.14±	1	β
1878.63	181.9	0.08	No certain elong.		....	....	1	β
1878.68	174.0	0.07	180?	....	+ 6	....	1	β
1879.77	35.4	0.25	150?	....	....	....	1	Hl
1880.60	27.8	0.36	29.0	0.35	+ 1.2	-0.01	5	β
1881.46	22.4	0.38	22.0	0.38	- 0.4	0.00	4	β
1882.62	13.0	0.26	11.9	0.31	- 1.1	+0.05	1	OΣ
1882.63	13.0	0.26	9.7	0.29	- 3.3	+0.03	3	β
1883.12	1.8	0.15	23	0.17±	+ 21	+0.02±	4	En
1883.55	303.0	.05	307.5	0.21	+ 4.5	+0.16	3	β
1884.70	73.5	0.07	17	0.23±	- 57	+0.16±	3	En
1885.95	30.3	0.33	25.5	0.29	- 4.8	-0.04	6	En
1886.84	24.4	0.39	23.4	0.47	- 1.0	+0.08	2	Hl
1886.87	24.2	0.39	24.5	0.35	+ 0.3	-0.04	6, 2	Sp
1886.91	23.9	0.39	23.2	0.47	- 0.7	+0.08	4	En
1887.78	18.4	0.34	15.2	0.49	- 3.2	+0.15	2, 1	Ho
1887.79	18.4	0.34	15.8	0.44	- 2.6	+0.10	5	Ta
1887.80	18.1	0.34	18.7	0.41	+ 0.6	+0.07	4	Hl
1887.86	17.6	0.33	15.0	0.33	- 2.6	0.00	11, 8	Sp
1888.60	8.1	0.20	33.4	0.35	+ 25.3	+0.15	4, 2	Lv
1888.69	6.0	0.19	9.9	0.25	+ 3.9	+0.06	4	β
1888.90	357.8	0.13	7.0	0.15	+ 9.2	+0.02	10, 14	Sp
1889.51	227.5	0.08	343.2	0.10	+ 115.7	+0.02	1	β
1889.82	201.1	0.11	193.1	0.2 ±	- 8.0	+0.09	1	Ho
1889.84	199.7	0.11	175.0	0.15	- 24.7	+0.04	3	Sp

COMPARISON OF OBSERVED AND COMPUTED PLACES—*Continued.*

DATES.	COMPUTED.		OBSERVED.		O — C.		No. OF NIGHTS.	Observers.
	θ	ρ	θ	ρ	$\Delta \theta$	$\Delta \rho$		
	°	"	°	"	°	"		
1890.88	40.8	0.18	Single		....	.....	3	Sp
1891.63	30.5	0.32	31.6	0.20	+	1.1 —0.12	5	β
1891.85	28.8	0.35	23.4	0.21	—	5.4 —0.14	5	Sp
1892.39	25.3	0.38	26.6	0.35	+	1.3 —0.03	4	β
1892.78	22.9	0.38	21.0	0.33	—	1.9 —0.05	2	Com
1892.91	22.2	0.38	22.8	0.30	+	0.6 —0.08	2	Sp
1893.84	15.1	0.29	14.9	0.22 $\pm$	—	0.2 —0.07 $\pm$	2	Com
1893.86	14.8	0.29	20.1	0.20	+	5.3 —0.09	2	Bar
1893.93	13.9	0.27	16.8	0.25	+	2.9 —0.02	6	Sp
1894.85	331.2	0.07	Single		....	.....	4	Sp
1895.61	194.5	0.10	Single		....	.....	1	Com
1895.70	178.2	0.08	Single		....	.....	2	L
1896.68	38.6	0.21	346.8	0.20 $\pm$	—	51.8 —0.01 $\pm$	1	Com
1897.72	27.6	0.36	30.9	0.24	+	3.3 —0.12	4, 2	Dob
1897.78	27.3	0.37	28.4	0.40	+	1.1 +0.03	3	Hu
1897.83	26.5	0.37	29.6	0.33	+	3.1 —0.04	4	A
1898.49	22.9	0.38	24.8	0.30	+	1.9 —0.08	4	A
1898.62	22.1	0.38	23.1	0.39	+	1.0 +0.01	6	Hu
1899.46	15.2	0.30	20.1	0.33	+	4.9 +0.03	3	A
1899.63	14.0	0.28	21.7	0.17	+	7.7 —0.11	1	Bo
1899.76	12.4	0.25	10.3	0.23	—	2.1 —0.02	1	L
1899.77	12.3	0.25	11.9	0.28	—	0.4 +0.03	1	Bry
1899.80	10.6	0.23	20.5	0.33	+	9.9 +0.10	4	Hu
1900.61	319.4	0.06	317.8	....	—	1.6	1	A
1900.75	265.7	0.05	287.2	....	+	21.5	1	A
1900.75	265.7	0.05	270.1	....	+	4.4	1	Hu
1900.79	252.8	0.06	275.3?	....	+	22.5	1	A
1900.86	235.9	0.07	264	....	+	28	1	A

In the above table and in the diagram, the abbreviations used to designate the observers are as follows: O Σ = OTTO STRUVE, Wl = WINLOCK, Sr = SEARLE, Du = DUNÉR, Pi = PIERCE, β = BURNHAM, Hl = HALL, En = ENGELMANN, Sp = SCHIAPARELLI, Ho = HOUGH, Ta = TARRANT, Lv = LEAVENWORTH, Com = COMSTOCK, Bar = BARNARD, L = LEWIS, Dob = DOBERCK, A = AITKEN, Hu = HUSSEY, Bo = BOYER, Bry = BRYANT.

EPHEMERIS.

M.	t—T.	t.	θ	ρ	M.	t—T.	t.	θ	ρ
°	y		°	"	°	y		°	"
0	0.000	1901.180	201.8	0.12	190	3.008	1898.488	22.9	0.38
10	0.158	.338	192.0	0.10	200	3.167	.647	21.9	0.38
20	0.317	.497	170.6	0.07	210	3.325	.805	20.9	0.37
30	0.475	.655	118.5	0.05	220	3.483	.963	19.8	0.36
40	0.633	.813	71.4	0.07	230	3.642	1899.122	18.7	0.34
50	0.792	.972	53.6	0.11	240	3.800	.280	17.5	0.33
60	0.950	1902.130	45.4	0.15	250	3.958	.438	16.0	0.31
70	1.108	.288	40.6	0.19	260	4.117	.597	14.4	0.28
80	1.267	.447	37.4	0.23	270	4.275	.755	12.4	0.25
90	1.425	.605	35.0	0.26	280	4.433	.913	9.9	0.22
100	1.583	.763	33.1	0.29	290	4.592	1900.072	6.5	0.19
110	1.742	.922	31.5	0.31	300	4.750	.230	1.3	0.15
120	1.900	1903.080	30.1	0.33	310	4.908	.388	352.3	0.11
130	2.058	.238	28.9	0.35	320	5.067	.547	332.3	0.07
140	2.217	.397	27.8	0.36	330	5.225	.705	282.3	0.05
150	2.375	.555	26.7	0.37	340	5.383	.963	235.1	0.07
160	2.533	.713	25.8	0.38	350	5.542	1901.022	215.4	0.10
170	2.692	1903.872	24.8	0.38	360	5.700	1901.180	201.8	0.12
180	2.850	1904.030	23.8	0.39					

ON THE PROGRESS MADE IN THE LAST DECADE
IN THE DETERMINATION OF STELLAR
MOTIONS IN THE LINE OF SIGHT.*

By H. C. VOGEL.

After the early attempts at the determination of the component in the line of sight of the motion of the stars by means of the spectroscope, which were made in 1868 by HUGGINS, in London, and in 1871 by myself at Bothkamp, on a few stars, extensive observations of this kind were conducted at the Observatory at Greenwich, extending over a period of thirteen years. The great persistence exhibited by MAUNDER in these observations, which were placed in his charge, is worthy of the more recognition in view of the slight interest which astronomers then generally had in the physical side of astronomy, and especially in view of their skeptical attitude toward the application of the

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spectroscope for determinations of motion. There was, indeed, some basis for this, inasmuch as a contention had arisen among the physicists as to whether the so-called Doppler's principle, which was recognized as experimentally correct for sound-waves, and which also permitted an easy theoretical explanation, could be justifiably transferred directly to light-waves. The striking proofs* of the admissibility of extending Doppler's principle to moving sources of light, furnished by the astrophysicists in the course of time, gradually silenced their opponents, foremost among whom were VAN DER WILLIGEN and SPÉE. We must not omit to mention, however, that an exhaustive theoretical treatment and explanation of the problem has not been given even up to the present time.

The protracted Greenwich observations of the stellar motions, which included forty-eight of the brightest stars, have demonstrated that direct observations with medium-sized instruments cannot furnish results whose uncertainty is of a less order than the average motion of the stars themselves. When the dispersion is just sufficient to permit the definite recognition of the displacement, which at most is slight, the intensity of the spectrum of even the brightest stars in a medium-sized instrument is too low to permit even a tolerably accurate measurement. A further reason for the small success doubtless lay in the unsuitability of the apparatus, which was especially lacking in stability.

When I made the first attempt in 1887, with the assistance of Professor SCHEINER, to record photographically the displacements of the lines in stellar spectra, and then to measure them as accurately as possible on the spectrograms, it very soon appeared that this constituted a very marked advance in the determination of these motions, which are so significant in stellar astronomy. The accuracy of the observations was increased more than eightfold with the apparatus constructed in 1888; the probable error, which in the Greenwich observations averaged $\pm 22^{\text{km}}$ for an evening, being brought down in the Potsdam observations to an average of $\pm 2.6^{\text{km}}$. We may therefore fairly say that the determination of motions in the line of sight thus first received a substantial basis in the spectrographic method, and thereby the widest prospects were opened for a period of new investigations and discoveries.

* I would refer to the introduction to Part I of Vol. VII of the Publications of the Potsdam Observatory, as well as to DUNÉR'S *Recherches sur la Rotation du Soleil*.

This success is doubtless due in the first instance to the application of photography; but we must not leave out of consideration that it is also in part due to the fact that a complete departure from previous principles was made in the construction of the apparatus, and an instrument was completed exclusively for this definite purpose, possessing the greatest possible stability. While spectroscopes are even yet constructed so that they can serve for many purposes,—permitting variations in the dispersion, and allowing measurements to be made in the most widely separated parts of the spectrum,—the Potsdam instrument photographs only a small portion of the spectrum in the neighborhood of the hydrogen line *H γ* . Its dispersion was so chosen that with sufficient sharpness of the spectrum a difference between the setting on a line of the star spectrum and one of the comparison spectrum could be determined under the measuring-machine with an accuracy corresponding to a motion of but a few kilometers. Where the spectrum of the star permitted, it was further arranged so that not only the position of a single line in the stellar spectrum was referred to that of a corresponding line in the comparison spectrum, but several lines were employed for the determination of the displacement. The accurate identification of the lines in the star spectrum was also attempted during the measurement by direct comparison with a plate of the solar spectrum.

I can restrict myself to these general statements, since the apparatus, as well as the methods of measuring the plates and reducing the observations, are sufficiently well known from the full descriptions given in Part I of Volume VII. of the *Publications of the Astrophysical Observatory*. But I desire to add something for the accurate description of the state of this branch of science at the conclusion of our series of observations at the beginning of the decade just past, and I also cannot withhold a critique of our observations from the standpoint gained by wider experience.

I would first point out that several of the precautions taken in the observations, which might appear as carried too far, were conditioned by an unsuitable telescope. The Potsdam 11-inch refractor is of very light construction, and has a wooden tube which occasions a strong effect of temperature in the alteration of the focal length. Although the wooden tube is conical, it has a very appreciable flexure.

In consequence of the slight stability of the telescope, an arrangement had to be thought out for bringing the star accurately upon the slit and holding it there in the proper position during the exposure of the photographic plate. This was accomplished by the simple means of simultaneously observing with a small telescope the image of the slit, illuminated by a Geissler tube, and the image of the star, reflected from the front face of the first prism. This method of guiding appears to have been adopted later by all observers who have undertaken determinations of velocities by the spectrographic method.

It is no longer indispensable with some of the more recent instruments, as for instance the great Potsdam refractor, since a guiding telescope of nearly the same focal length is attached to the telescope itself.

Although it was my endeavor to develop something entirely new in constructing the stellar spectrograph in 1888, in respect to the prisms I was under the influence of the times, and chose the compound prisms known as Rutherford's, which then were considered the most excellent, and in fact possessed the advantage of giving less deviation for the same dispersion, and hence less curvature of the spectral line, and which caused less loss by reflection on account of the less oblique incidence of the rays. Extensive investigations made here at a later time have shown that simple prisms are preferable, and elsewhere the use of prism systems has continually decreased. In observations with the spectrograph we have had the experience that strains occur in the cemented prisms at temperatures below -2° , causing a diffuseness of the spectra. A consequence of the above mentioned large flexure of the wooden tube of the 11-inch refractor may be that in many positions of the telescope the collimator and the prism are not fully utilized; except for a slight loss of light, this would have no injurious effect on the observations under conditions of good adjustment, perfect surfaces of the prisms, and complete homogeneity of the masses of glass used for the prisms.

As above stated, however, tensions in the prisms and consequent departures from homogeneity in the glass have shown themselves distinctly at low temperatures, which have caused not only a diffuseness of the spectra and a consequent diminished accuracy, but also have not been without effect on the displacement of the lines. Although this effect may have been exceedingly slight in most cases, it may nevertheless have become

appreciable in unusual positions of the telescope, such as occur for stars near the pole, and possibly the large discrepancies for a few stars between our observations and those of other observers may be thus explained. In our observations we have always used the telescope in that position only (east or west) in which the optical axis of the collimator and telescope were adjusted. It was not possible to determine subsequently the effect of a lack of coincidence of the two axes on the displacement of lines in the spectra; this, moreover, could hardly have been determined at the time of observation, since it depends on the changes of temperature in the prisms, and the tension thereby occasioned, as well as upon the declination and the hour-angle. The determination of the true temperature of the prisms is in general beset with difficulties, and the determination of the temperature of the separate parts of the prisms is, therefore, hardly to be thought of. We might infer that the errors arising would balance each other in a great number of observations made under the greatest variety of conditions. It would, however, probably be possible to obtain later data as to the errors dependent upon the position of the spectrograph, from a comparison of the Potsdam observations with the results obtained by other observers and with other instruments.* Such errors are hardly to be expected in the newer instruments with simple prisms, and having greater stability of the telescope. We have most carefully studied the effect of the temperature on the focal length of the objective of the refractor and upon the focal length of the objectives of the collimator and camera, as well as the varying dispersion of the prism with the temperature, and we have taken them into account both in the observations and in the reductions of the measures.

The hydrogen spectrum was in nearly all cases used as a comparison spectrum, though attempts were made to use the

* At present I am acquainted with determinations of the motions of only something more than half of the objects observed in Potsdam, made by BÉLOPOLSKY, CAMPBELL, NEWALL, and LORD, for the great part of which I am indebted to letters of Messrs. BÉLOPOLSKY and CAMPBELL. The comparison of these with the Potsdam observations leads to the following provisional results. The departure of the Potsdam results from those of the above observers averages $\pm 2.8 \text{ km}$ for 23 objects, and the comparison shows with some certainty that the Potsdam values on the average are 1.2 km too large for stars of negative motion, and 0.7 km too small for those of positive motion. This constant departure is more clearly pronounced if we consider CAMPBELL's observations only. Taking the mean from 19 objects the departure $V. S. - C. = \pm 2.7 \text{ km}$; the negative velocities were found on the average to be 2.5 km larger and the positive velocities 1.6 km smaller by VOGEL and SCHEINER than by CAMPBELL. If we apply these average values to the observations, the mean value of the difference $V. S. - C.$ comes out as $\pm 2.0 \text{ km}$.

magnesium line $\lambda 448 \mu\mu$, which possesses the advantage of being very sharp in some star spectra, while the *Hy* line is broad and diffuse; but without success, since this line is diffuse in the spark spectrum. The iron spectrum may also be used, and I have pointed out the advantages gained in the use of this spectrum, as well as that of other metallic substances, have described the method of observation, and have illustrated it by an example—the spectrum of *Sirius*.* It would have been better for this purpose to have used the spectrum of a *Cygni* or of a star of the second class, because the lines in the spectrum of *Sirius* are exceedingly fine. For *Sirius* the probable error of the motion in the line of sight obtained from the difference between a single line in the star spectrum and a single line in the comparison spectrum is $\pm 1.34^{\text{km}}$; so by the use of nine such pairs the probable error of the measurements of the plate would not be more than $\pm 0.45^{\text{km}}$.

The observations could be made on only forty-seven of the brighter stars, since the spectrum of a star fainter than 2.3 magnitude with an exposure of about an hour did not have sufficient intensity to be measured with accuracy. With a longer exposure the practically unavoidable changes in temperature produced such an influence on the spectrograph that the accuracy of the observation was impaired. As a guard against accidental errors, it was intended that each star should be observed on at least two nights. At the time when these observations were begun, the possibility that a star might show changes in its motion in the line of sight, in a short time, had not been thought of; yet out of these forty-seven stars four had already been found to have a periodic variation during the progress of the work.

The object of this work on the motion of stars in the line of sight, completed in 1891, was first to demonstrate the usefulness of the spectrographic method for instruments of medium size, and further, by means of a thorough and detailed description of methods, to enable an observer equipped with better instruments to carry on observations of this character; and possibly to give the method still further development. There was no need of our repeating these observations in the next few years with the same instrument, while we hoped that in the near future we should be able to extend them with more powerful optical means. Unfortunately the realization of this hope was deferred from

* *Sitz. d. k. Acad. d. W. Berlin*, No. 28, 533, 1891.

year to year, and not until the present year did it again become possible for us to carry on regular observations at the Potsdam Observatory—this time, however, with instruments of the highest order of excellence.

Now, while the seed which we planted ten years ago has not hitherto received in Potsdam the nourishment which we could have wished, yet I have the pleasure of knowing that it has found nourishment in other places, so that it has thriven greatly, and has already blossomed beyond our highest expectations.

In 1890 and 1891 KEELER made his beautiful observations on the radial velocity of the brighter nebulae, by means of a grating spectroscope attached to the great refractor of the Lick Observatory. Fourteen nebulae were examined for motion, and the determinations of these motions are of remarkable accuracy, considering the great difficulty of the observations. The probable error of the result for each nebula, a result which is the mean of several observations, is on the average only $\pm 3.2^{\text{km}}$. Of the fourteen nebulae, nine have a negative and five a positive motion, referred to the Sun. The average motion is 27^{km} , and therefore, if we are justified in drawing a conclusion from so small a number of observations, is of the same order as that of the brighter stars. The greatest velocity, -65^{km} per second, is that of the well-known planetary nebula *G.C. 4373*, *H IV 37*. It exceeds by about 10^{km} that of *a Tauri*, which has the greatest velocity of any of the brighter stars of the northern heavens.

While making these observations on nebulae, KEELER determined the radial velocities of *a Bootis*, *a Tauri*, and *a Orionis*. He found for the velocity of *a Bootis*, from nine measures during 1890 and 1891, a value of $-6.8^{\text{km}} \pm 0.3^{\text{km}}$; for *a Tauri*, on three evenings, $+55.2^{\text{km}}$, and for *a Orionis*, on two evenings $+14.0^{\text{km}}$ per second. The probable error of a single evening's observations, deduced from the results for the three stars, averages $\pm 1.8^{\text{km}}$.

The Potsdam observations made from 1888 to 1890 give for these three stars the values: $-7.6 \pm 0.6^{\text{km}}$, $+48.5^{\text{km}}$, and $+17.2^{\text{km}}$. A better agreement, considering the complete independence and entirely different character of the methods used (KEELER made his measures on the D lines), could hardly be expected. With the Lick refractor, which exceeds the Potsdam

11-inch refractor some eight times in light-gathering power, it has therefore been possible to determine the motions of the brighter stars, by direct observation, with about the same accuracy as with the Potsdam refractor by the spectrographic method.

About the end of the year 1891, the great Pulkova refractor of 76^{cm} aperture was provided with a spectrograph, built exactly according to the model of the Potsdam instrument, and like the latter provided with two Rutherford prisms. The instrument was so arranged that the prism-box could be removed, and another, containing only a single prism, substituted for it when faint objects were to be observed with small dispersion. Since the refractor had been intended primarily for micrometric work, and only secondarily for spectroscopic, the telescope and observing-chair had been designed mainly with reference to the convenience of the observer at the micrometer. For this reason BÉLOPOLSKY had to contend with many difficulties before he finally succeeded, after making a number of considerable changes in the telescope and the observing-chair, in making spectrographic observations with accuracy. The very unsuitable climate made it necessary for him to abandon his original plan of observing the motions of the fainter stars, a plan which may be regarded as an extension of the Potsdam observations. He therefore selected special objects from among the variable and double stars for his observing-list, and made observations of their motions.

Among his valuable researches should be mentioned his investigations of δ *Cephei**, in which he demonstrates the existence of a periodical variation in the velocity of this star in the line of sight, which could be brought into good agreement with the period of its light curve, 5^d 9^h. In the case of η *Aquilæ*† he discovered a variation in the velocity which found an explanation in the period of light-variability of 7^d 4^h; and finally he found a change in the velocity of α *Geminorum*‡ with a period of 2^d 23^h.5. It soon appeared that the line of apsides of this double-star system was in rapid revolution, and from careful investigation the period of this motion was found to be 4 years 40 days.§

As the interesting double spectrum of the well-known variable β *Lyræ* was known, from spectrographic observations, to contain pairs of bright and dark lines, and since changes in the relative

* *Astrophysical Journal*, Vol. 1, 160. *A. N.*, Vol. 140, 17.

† *Mem. Spett. Ital.*, Vol. 26, 101.

‡ *Bull. Acad. St. Petersburg*, No. 4, 341. *Astrophysical Journal*, Vol. 5, 1.

§ *Mem. Spett. Ital.*, Vol. 26, 101, and Vol. 28, 103.

positions of these lines had been discovered which were connected in some way with the period of variability of $12^d.9$, PICKERING attempted to calculate the orbit of this hypothetical double star from measures of the distances between the double lines at different phases of the light period. He found a relative velocity of the components of 482^{km} per second, and a diameter of the orbit, assuming it to be circular, of 85.3 million kilometers. I have more recently pointed out that the distance between the lines, and therefore the relative velocity of the components, has been taken to be too large, by not taking into account a probable overlapping of the lines; since the above value leads to an enormous mass (1500) of the system. BÉLOPOLSKY has published an extensive investigation* of β *Lyræ*, based on observations made with the Pulkova refractor, in which are contained many interesting details concerning the changes which take place in the pairs of bright and dark lines during the period of the star's variability. From his measures of the hydrogen line *H* β he found an orbital velocity of 89^{km} per second, a semiaxis of 15 million kilometers, and hence a mass of the system of the same order as that of the Sun.

In 1894, while examining a large mass of observations of β *Lyræ* made with a small single-prism spectrograph attached to the photographic refractor of the Potsdam Observatory,† I found clearly a certain agreement between the relative displacement of the lines and the period of light variability, but not of the simple character assumed by BÉLOPOLSKY. The variation in the distance between the bright and dark line *H* ζ , especially, seemed to correspond to a period much longer than the period of the light variation, so that a system of two bodies was no longer adequate to explain the phenomena observed in the spectrum. Now since it has been shown by MYERS that the light curve is very satisfactorily represented under the assumption of a double-star system, we are compelled to introduce explanations which depend upon phenomena of a physical nature.

BÉLOPOLSKY‡ thereupon, in 1897, resumed his investigations, and from them there is no doubt that we have come nearer to a decision as to the nature of β *Lyræ*. In his measures he disregarded the bright lines altogether, and restricted himself to the

* *Bull. Acad. St. Petersbourg*, N. S., No. 4, 341. *Mélanges mathem. et astr.*, Vol. VII. Livr. 3, 1893.

† *Sitz. d. K. Akad. d. W. Berlin*, 1894, 115.

‡ *Mem. Spettro. Ital.*, Vol. 26, 135; also Tikhoff, *ibid.*, Vol. 26, 107.

dark magnesium line $\lambda 448 \mu\mu$, which has no companion emission line, and thus freed them from the influence of a partial overlapping. By so doing he was able to obtain results which were referable to the case of a simple double star without further complication. He found for the orbital velocity 178^{km} per second, for the semiaxis of the orbit 31.9 million kilometers for the distance between the two components 47.5^{km} , and for their masses respectively 9 and 18 times the Sun's mass.

BÉLOPOLSKY has also found variable motion in λ *Tauri*, ζ *Geminorum*, and θ *Ursæ Majoris*,* so that his contribution to the discovery of spectroscopic binaries consists of seven objects.

It is of interest to note here the great velocity of -70^{km} per second, referred to the Sun, which BÉLOPOLSKY has found for ζ *Herculis*.† CAMPBELL,‡ at the Lick Observatory, has confirmed this observation and obtained a value of -70.3^{km} , while DESLANDRES,§ at Paris, obtained a value about 10^{km} smaller. In this connection I may remark that CAMPBELL has found in η *Cephei* the greatest known velocity of a star in the line of sight (-87^{km} per second). This velocity would probably be reduced somewhat if we were to take into account the motion of the solar system. Assuming the co-ordinates of the apex of the Sun's way to be $\alpha = 267^\circ$ and $\delta = +31^\circ$, and the velocity of the Sun to be 17^{km} per second, we get for the absolute component of the velocity in the direction of the Sun, -74^{km} per second for η *Cephei*, -54^{km} for ζ *Herculis*, and -51^{km} for the nebula *G. C. 4373*.

In publishing his observations of ζ *Herculis*, DESLANDRES made a remark concerning the Paris telescope of 1.2 meters aperture, to which his spectroscope was attached, from which it appears that the stability of the telescope is hardly what it should be for such delicate investigations; and, possibly because the mirror did not unite perfectly all the rays on the slit, the exposure had to be made 50 per cent. longer than with the Pulkova refractor, under presumably less favorable atmospheric conditions. In these unsuitable conditions may also be found the reason why so few observations of stellar motion by DESLANDRES have been made known. He has published beautiful three-fold enlargements of the original spectrograms || of the four stars α *Aurigæ*, β *Aurigæ*, α *Canis Majoris*, and γ *Pegasi*, which are

* *A. N.*, Vol. 145, 281; also Vol. 149, 239, and Vol. 151, 39.

† *A. and A.*, February, 1894. *A. N.*, Vol. 133, 257.

‡ *Astrophysical Journal*, Vol. 8, 157. § *C. R.*, Vol. 119, 1252.

|| *Spécimens de Photogr. Astronomiques. Obs. de Paris*, 1897.

specially remarkable for the great length of spectrum which his apparatus is capable of defining sharply. With the exception of a series of observations of *α Aquilæ*, nothing further is known to me of work on the motions of stars at the Paris Observatory.

At the suggestion of POINCARÉ of Paris, DESLANDRES has, on the other hand, made spectrographic researches on the motion of the planets, and on the rotation of *Jupiter*,* which are of importance. The investigations showed, in accordance with POINCARÉ's assumptions, that in the case of a body which shines by diffuse reflected light, the displacement of lines in its spectrum depends not only on the motion of the body with reference to the observer, but also on the motion of the body with reference to the source of light by which it is illuminated.† The observations on the rotation of *Jupiter* have been repeated and confirmed by BÉLOPOLSKY.

The beautiful results which KEELER obtained by the spectrographic method at the Allegheny Observatory on the rotation of the ring system of *Saturn*, should be mentioned in this connection. By these observations it was shown that *Saturn's* rings consist of separate small bodies which revolve about *Saturn* in obedience to KEPLER's laws, and cannot be regarded as a rigid body, thus furnishing a practical confirmation of the conditions demanded by theory.‡ These interesting observations have been repeated by CAMPBELL, BÉLOPOLSKY, and DESLANDRES.

The first attempts to prove the truth of Doppler's principle, by showing that there is a displacement of the lines in the spectrum of the edge of the Sun near the equator which corresponds to the known equatorial velocity obtained from observations of sun-spots, were made by me twenty-nine years ago. In the course of time these observations have been frequently repeated with improved instruments. DUNÉR, in Lund, has undoubtedly carried out the most thorough investigation of the rotation of the Sun in different zones, by means of spectroscopic methods.§

* *C. R.*, Vol. 120, 417. † *A. N.*, Vol. 139, 241.

‡ KEELER used in these observations a spectrograph composed of three simple prisms, which produced a total deviation of 180°. From a few original negatives of the solar spectrum and several excellent negatives of planetary spectra, which he kindly sent me, I was able to see that the apparatus is very similar to the Potsdam spectrograph of 1888, both as regards dispersion and resolving power. The dispersion of KEELER's apparatus is about one-twentieth greater than that of the Potsdam spectrograph, while the resolution of close lines is almost exactly the same in both instruments. Perhaps KEELER's apparatus is slightly superior to the Potsdam apparatus in this respect.

§ N. C. DUNÉR: "Recherches sur la Rotation du Soleil." *Nova Acta Reg. Soc. Sc. Ups.* Series III.

He was induced to make these observations because, in the beginning of the 'eighties, the trustees of the Lars Hjertas Minne endowment expressed a desire to have the spectroscope used for a careful investigation of the question whether the wave-length of light really varies directly as the velocity of the source of light, as required by the Doppler-Fizeau principle, and had expressed their willingness to grant sufficient money for a suitable spectroscope.

To give some idea of the results of his observations, which were made during the summer months of the years 1887, 1888, and 1889, I have inserted the following table of the means for various heliocentric latitudes, with their probable errors:—

Heliocentric latitude.	Velocity in km.	Number of observations.	$\xi \cos \phi$	ξ
0°.4	1.08 $\pm$ 0.013	107	14°.14	14°.14
15°.0	1.85 0.013	104	13°.19	13°.66
30°.0	1.58 0.014	104	11°.31	13°.06
45°.0	1.19 0.014	106	8°.48	11°.99
60°.0	0.74 0.012	107	5°.31	10°.62
74°.8	0.34 0.013	107	2°.45	9°.34

Shortly before the completion of DUNÉR's researches there appeared two extended investigations by CREW† on the same subject, which led to the result that the absorbing layer of the Sun rotates with a uniform angular velocity, while DUNÉR's observations cannot be harmonized with the assumption of a constant angular velocity, as is shown by the table, in which the angular velocity (ξ and $\xi \cos \phi$) is given in the last two columns. This is not the place to discuss the difference between the results obtained by the two observers; for it was merely my purpose to mention the beautiful observations which have been made in this field, and to show what great accuracy can be given to spectroscopic observations of motion when there is sufficient light. The observations of DUNÉR agree very well with the law of the rotation of the Sun derived from the observations of the sun-spots.

With regard to the above-mentioned desire of the trustees to ascertain whether the change in the wave-length of light is proportional to the velocity of the luminous source, DUNÉR's observations have shown that, within the errors of observation, the simple form of Doppler's principle is valid, and the influence of possible higher terms is not recognizable.

† HENRY CREW: "On the Period of the Rotation of the Sun as Determined by the Spectroscopie." *Am. Jour. Sci.*, Vol. 35, 151, and Vol. 38, 204.

Through the generosity of Mr. D. O. MILLS, Professor HOLDEN, at that time Director of the Lick Observatory, was able to have a spectrograph constructed for the Observatory about the middle of the nineties, to be used exclusively for determining stellar motions in the line of sight. In the October, 1898, number of the *Astrophysical Journal*, Professor CAMPBELL has given an extended description of this instrument, which mainly through his endeavors has become the most noted instrument of its time.

Attached to the great 36-inch refractor of the Lick Observatory, used under the most excellent atmospheric conditions, and in the hands of a circumspect and careful observer, the Mills spectrograph has in the last few years achieved surprising results. The spectrograms taken with it possess, on the average, a sharpness which excels that of even the best spectrograms taken with the Potsdam apparatus of 1888, and the resolving power of the instrument is much greater. Through the kindness of Messrs. KEELER and CAMPBELL, I received last year two original negatives, one of γ *Andromedæ*, and the other of η *Pegasi*; so that I was able to thoroughly assure myself of their excellence. They are marked as being above the average excellence, and their measurement is a real pleasure; yet even with such plates great care and long experience are required to obtain uniformly consistent results.

With spectra which contain many lines, and which differ considerably from the solar spectrum, the use of a solar spectrum in measuring the plates cannot well be avoided. In many spectra, on the other hand, especially those with strong iron lines, the stellar and comparison spectra can be compared directly by means of HARTMANN's interpolation formula.* The amount of the shifting of a known line in the star spectrum can be exactly determined even if there is no identical line in the comparison spectrum; for instance, the lines of hydrogen and clèveite gas can be compared with iron lines in the comparison spectrum.

On CAMPBELL's plates the probable error of the determination of the distance between a stellar line and the corresponding comparison line may be taken as $\pm 1.2^{\text{km}}$, and since from ten to twenty measurable lines may easily be found in the spectrum of a star of class II, the probable error of the mean of the measures on a single plate may be reduced to about $\pm \frac{1}{3}^{\text{km}}$. Slight

**Publ. des Astrophys. Obs. zu Potsdam*, Vol. 12, No. 42.

changes in the instrument during the exposure, slight differences in the observer's habit of measurement, minute distortions of the film, and other unavoidable sources of error have here to be taken into account. They are recognizable in the fact that the probable error of the final result, deduced from the mean of several plates of the same object, is larger than that which the probable error of a single plate, determined from the agreement of the different lines, would lead one to expect. According to CAMPBELL'S observations of the brighter stars, the probable error of a single plate is, however, somewhat less than $\pm 1^{\text{km}}$. CAMPBELL'S detailed description of the Mills spectrograph, and the opportunity I have had of examining some of the spectrograms made with it, have been of great service to me, since the new spectrographs for the large Potsdam refractor, which have been made from my designs by TOEPFER, of Potsdam, were just at that time so nearly completed that they could be subjected to a preliminary test. The construction of these two spectrographs was begun in 1897. One of them has three simple prisms, and a total deviation of 180° , while the other has only one simple prism. Dr. HARTMANN, whom I had commissioned to make the adjustments and tests of the optical parts of these spectrographs, has devoted all his energies to obtaining the highest degree of excellence,* and it is a pleasure to be able to say that the new spectrograph with three prisms for the Potsdam 80^{cm} refractor will not be inferior to the Mills spectrograph.

At the present time a series of observations of the radial velocities of stars down to the fifth magnitude is being made at the Lick Observatory. So far Professor CAMPBELL has made two or more observations on about 300 stars, and has found 16† of them to have a variable velocity, thus bringing the number of binaries discovered by spectrographic methods up to 28. I shall merely give here a list of the spectroscopic binaries discovered by CAMPBELL.‡

Star.	Period.
η Pegasi	2¼ years.
χ Draconis	9½ months.

* For particulars on this investigation, and the methods used in testing, see Dr. HARTMANN'S paper in *Astrophysical Journal* for June, 1900, and following numbers.

† Since the announcement of these sixteen spectroscopic binaries, the observations with the Mills spectrograph have led to the discovery of thirteen additional systems; placing the total for the Lick Observatory at twenty-nine.—*Pub. Com. A. S. P.*

‡ *Astrophysical Journal*, Vols. 8, 9, 10.

α Leonis	14½ days.
ζ Geminorum	Unknown.
ι Pegasi	Over 10 days.
θ Draconis	Over 9 days.
ϵ Libræ	Unknown, several months.
β Capricorni	Unknown, long.
h Draconis	Undetermined.
λ Andromedæ	About 20 days.
ϵ Ursa Minoris	A few weeks.
ω Draconis	Unknown.
α Ursa Minoris	39 days and a second longer period.
α Aurigæ	3½ months.
ν Sagittarii	A few weeks.
β Herculis*	Unknown, 1 year?

It is worthy of remark that several stars have a period of many months, and that η Pegasi has a period of $2\frac{1}{4}$ years. Thus the gap which formerly existed between the spectroscopically discovered and the visual double stars, with respect to the lengths of their periods of revolution, has been filled up.

When we consider the large number of variable stars of the *Algol* type which have been discovered photometrically during the last decade, and for which the assumption appears to be justified that their variation is a consequence of duplicity; when we further consider that these stars can be recognized as variable only when the line of sight makes an extremely small angle with the plane of the orbit, and that for the spectroscopically discovered stars, also, this angle cannot be supposed to be very great, we cannot repress our astonishment at the rapidity with which the number of stars thus discovered has grown.

Among the double stars discovered at the Lick Observatory, *Polaris*, which has a double period of motion in the line of sight, is of particular interest, since we are here led to infer the existence of three bodies. The discovery of the short period is an admirable proof of the excellence of the observations, since the variation from the mean velocity is only $\pm 3^{\text{km}}$.

Of particular interest, also, is the discovery of the periodic doubling of the lines in the spectrum of α Aurigæ, which consists of two superposed spectra uniting at times to form a spectrum strongly resembling that of the Sun.† Although α Aurigæ

* *A. S. P.*, Vol. 12, 39, 1900.

† From CAMPBELL'S observations the deduction can also be made that both stars, one having a spectrum similar to the solar spectrum, and the other a spectrum containing the hydrogen and the stronger iron lines, are of nearly the same mass, since their dis-

was frequently observed at Potsdam during the years 1888-1891, this peculiarity of its spectrum escaped us, and the explanation of the fact that most of our spectrograms of *a Aurigæ* are ill-defined and the lines quite extraordinarily broadened, was only given later, by the investigations of CAMPBELL. The days on which the spectrograms obtained were good and sharp, are those on which the two spectra were superposed, and our early observations have now at least given us the means of arriving at a more accurate value of the period ($104^d.1 \pm 0^d.2$). By means of observations with the new Potsdam refractor and spectrograph, we have been able to confirm CAMPBELL's observations, both of *a Aurigæ* and *a Ursæ Minoris*.*

When we consider that researches on the motions of stars in the line of sight have been begun and are being carried on with good results by NEWALL, in Cambridge, and by LORD, at the McMillin Observatory in Ohio; that in Meudon a double refractor of the same size as the Potsdam instrument has been set up, and provided with a spectrograph, with which DESLANDRES† has already succeeded in showing that δ *Orionis* is a star with variable velocity; that further, the largest instrument in the world, Yerkes refractor at Williams Bay, will also be used for this purpose, and that GILL, with the double refractor of the observatory at the Cape of Good Hope, will extend the same researches to the southern heavens, we may confidently expect that our knowledge of the stellar system to which we belong will be increased as much in the new century upon which we are entering as our knowledge of the solar system has been increased in the century just past. The energy with which some of the largest observatories in the world are participating in the work is most encouraging, for the amount of work to be done has grown most unexpectedly during the last decade, through the discovery of so many stars having a variable velocity in the line of sight.

In closing this review, I should not wish to leave unmentioned the fact that in one case the application of the Doppler-Fizeau principle can no longer be regarded as valid; I refer to the

placements from the mean position are about equal. Assuming the period to be $104^d.1$ and the maximum relative velocity to be $\pm 30 \text{ km}$, and assuming provisionally that the orbit is nearly circular, with its plane in the line of sight, I have found, for the combined mass of the stars, $m+m_1=2.3 \odot$, and for their distance, 85.3 million km.

* It should be added here that the discovery of the duplicity of the lines of *a Aurigæ* was made independently, and almost simultaneously, by NEWALL, of Cambridge, England.

† C. R., Vol. 130, No. 7.

interpretation of the pairs of bright and dark lines which are found in the spectra of the new stars. When this peculiarity of the spectra of new stars was discovered, it was very natural that the relatively strongly displaced emission and absorption lines should be ascribed to the spectra of two bodies, whose motions in the line of sight were oppositely directed. Corresponding to the great displacement of the lines, velocities were arrived at which, in comparison with the mean velocity of other heavenly bodies whose motions have been spectroscopically determined, must be characterized as perfectly enormous—more particularly since it was improbable that the whole motion of the bodies should be in the line of sight.

But since in the stars which have appeared more recently, *Nova Normæ* and *Nova Carinæ*, the same pairs of bright and dark lines were found, in which, as in the spectrum of *Nova Aurigæ*, the emission line lay on the less refrangible side; and since similar lines can be observed in the spectra of β *Lyræ* and *P Cygni* (the *Nova* of 1600); and particularly since no change in the distance between the bright and dark lines could be detected during the whole of the first apparition of *Nova Aurigæ*, and the lines remain unchanged in position in the spectrum of *P Cygni*—while in β *Lyræ*, though they vary during the star's period, the changes are never so great as to reverse the positions of the dark and bright lines—doubts as to the applicability of Doppler's principle to such cases appeared to be more and more fully justified.

The assumption that we are here concerned with phenomena of a purely physical nature gained a firmer basis through the researches of HUMPHREYS and MOHLER, EDER, and WILSING,* on the changes produced in spectral lines by high pressure. It was found that under high pressure pairs of bright and dark lines could be produced in metallic spectra, in which the emission line always lay on the less refrangible side.

These observations are to be regarded as only first beginnings; but doubtless through them a wide field of highly interesting research is opened, in which the astronomer may hope for the zealous support of the physicist. The veil which has enveloped anew our knowledge of the nature of the temporary stars will certainly be lifted, when experiment shall yield results which

* "Ueber die Deutung des typischen Spectrums der neuen Sterne." *Sitz. d. K. Akad. d. W. Berlin*, Vol. 24, 425. 1899.

harmonize with the phenomena observed in them; and not until then will the time come to frame hypotheses respecting the origin of the abnormal conditions of pressure in their atmospheres.

It is quite possible that, as observations of motions in the line of sight become more and more refined, the conditions of pressure in the atmospheres of the stars can no longer be neglected, although it may be assumed that the pressure in the atmospheric layers from which the light comes to us is neither subject to great variations for any individual star, nor varies widely for different individuals. Even if this should not be true, the means of arriving at accurate results for stellar motion, and at the same time of gaining information concerning the conditions of pressure in the stellar atmospheres, is to be found in the use of different metals for comparison spectra.

THE ORBIT OF *99 HERCULIS* = A. C. 15.

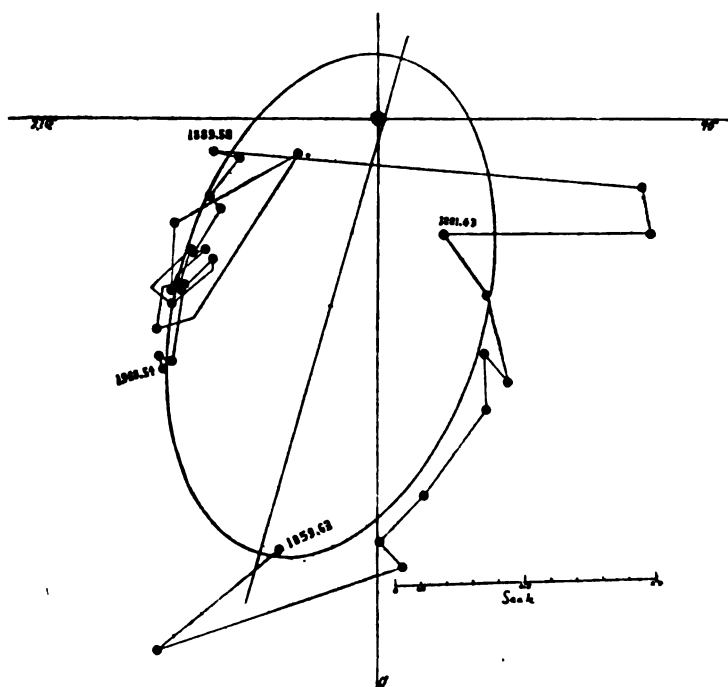
BY R. G. AITKEN.

The faint companion to *99 Herculis* was discovered by ALVAN CLARK in 1859, and the first measures of it were secured by DAWES in the same year. OTTO STRUVE measured it on five nights during the next twenty years, but otherwise it was wholly neglected until BURNHAM began work with the 18½-inch Dearborn refractor in 1878.

The measures indicated motion, but whether this was rectilinear or orbital it was impossible to say until 1889. In that year BURNHAM observed the pair with the 36-inch telescope of the Lick Observatory, and found that the small star had passed over an arc of more than 180° since his observation in 1881. It was at once evident that the system was binary, with a moderately short period.

In the last ten years the star has been observed frequently, but the great difference in the brightness of the two components, and their small angular separation, make it a difficult object, and the measures are discordant.

The following are all the published observations:—



THE ORBIT OF 99 HERCULIS.

DATE.	Pos. Angle.	Dist.	n.	Observer.	O - C.	
					$\Delta \theta$	$\Delta \rho$
1859.63	347 ^c .2	1".70	2	DAWES	- 2 ^o .4	- 0".03
60.30	337 .4	2 .22	1	O. STRUVE...	- 12 .9	+ 0 .50
66.68	3 .1	1 .73	1	"	+ 5 .0	+ 0 .15
68.50	0 .1	1 .63	1	"	- 0 .7	+ 0 .11
72.56	7 .0	1 .46	1	"	- 0 .5	+ 0 .12
77.56	20 .7	1 .19	1	"	+ 1 .3	+ 0 .15
78.46	24 .4	0 .99	3	BURNHAM....	+ 2 .0	+ 0 .01
79.47	26 .5	1 .13	1	"	+ 0 .1	+ 0 .23
80.53	31 .6	0 .80	2	"	+ 0 .5	$\pm$ 0 .00
81.43	29 .4	0 .51	1	"	- 6 .9	- 0 .22
83.65	75 .4	1 .14	2	O. STRUVE...	...	....
88.54	67 .2	1 .05	1	"	...	....
88.73	Apparently single.		36-inch.	BURNHAM....	....	....
89.50	281 .2	0 .65	1	"	+ 16 .7	+ 0 .22
90.45	285 .1	0 .56	3	"	+ 6 .6	+ 0 .03
91.56	294 .4	0 .72	3	"	+ 5 .1	+ 0 .07
92.40	299 .2	0 .70	3	"	+ 4 .0	- 0 .04
94.74	305 .7	0 .88	1	COMSTOCK...	- 0 .7	- 0 .07
95.30	307 .0	0 .84	1	SEE	- 1 .3	- 0 .15
95.46	309 .5	1 .04	6	BARNARD....	+ 0 .6	+ 0 .04
95.61	297 .2	0 .89	1	HOUGH	- 12 .1	- 0 .13
95.65	293 .4	0 .34	2	LEWIS	- 16 .0	- 0 .68
95.73	313 .4	....	2-0	MOULTON ...	+ 3 .7	....
95.73	315 .2	1 .18	3-2	SEE	+ 5 .5	+ 0 .15
95.80	309 .6	1 .00	3	COMSTOCK...	- 0 .3	- 0 .03
96.62	305 .0	0 .85	2	LEWIS	- 7 .3	- 0 .25
96.65	311 .9	1 .07	3	COMSTOCK...	- 0 .5	- 0 .03
96.70	310 .3	0 .84	4-3	AITKEN	- 2 .3	- 0 .26
97.54	311 .1	1 .00	4	"	- 3 .8	- 0 .15
98.54	310 .4	0 .99	2	LEWIS	- 6 .9	- 0 .23
99.29	319 .6	1 .23	2	HUSSEY	+ 0 .7	- 0 .04
99.34	317 .3	1 .25	3	AITKEN	- 1 .7	- 0 .02
1900.54	319 .0	1 .27	4	"	- 2 .4	- 0 .06

All the complete observations have been plotted to scale, and are represented in the figure (p. —) by the small black circles. Their order in time is indicated by the broken line. A mere inspection of the figure shows how impossible it is to satisfy all of the observations. Some of the most discordant ones must be entirely neglected. Indeed, it is very doubtful whether the measures by OTTO STRUVE in 1883, and especially those in 1888, refer to the real companion at all. In the latter year the distance was almost certainly as small as 0".5, and the pair therefore

exceedingly difficult. In fact, BURNHAM noted it as single with the 36-inch refractor in that year.

After many trials, the ellipse shown in the figure was adopted as the best that could be drawn at present, and from it the following set of elements was derived:—

$$\begin{array}{ll} P = 63 \text{ .0 years.} & \Omega = 154^{\circ}.7 \\ T = 1887 \text{ .0} & i = 24 \text{ .7} \\ e = 0 \text{ .76} & \lambda = 11 \text{ .3} \\ a = 1'' \text{ .00} & n = + 5 \text{ .7143} \end{array}$$

How nearly these elements satisfy the observed positions may be seen by examining the two columns of residuals following the names of the observers in the table.

A comparison of the above elements with those previously published by GORE and SEE, seems to indicate that the eccentricity and the major semiaxis of the orbit, and the time of periastron passage are fairly well known. The other elements differ widely, as the following tabulation shows:—

	P	T	e	a	Ω	i	λ
GORE...	53.55	1885.58	0.7928	1''.12	50°.1	38°.6	110°.73
SEE.....	57.5	1887.30	0.806	1 .163	77 .0	35 .5	90 .0
SEE.....	54.5	1887.70	0.781	1 .014	Indeter- minate.	0 .0	169 .5*
AITKEN.	63.0	1887.0	0.76	1 .00	154 .7	24 .7	11 .3

* The angle of periastron, as the apparent and real orbits are identical.

The present elements, like the preceding ones, can only be considered as preliminary, and it will be many years before a satisfactory orbit can be computed, for the motion of the small star at present is very slow. A short ephemeris is:—

1901.50	323°.2	1''.38
1902.50	325 .0	1 .43
1903.50	326 .6	1 .47
1904.50	328 .1	1 .51
1905.50	329 .5	1 .55

October, 1900.

PLANETARY PHENOMENA FOR JANUARY AND
FEBRUARY, 1901.

BY MALCOLM MCNEILL.

JANUARY.

The Earth is in perihelion at noon on January 2d, Pacific time.

Mercury passed greatest west elongation in December, and is too near the Sun when January begins to be easily seen. It rapidly approaches the Sun, passes superior conjunction on January 21st, and becomes an evening star, but does not recede far enough from the Sun to be seen with the naked eye before the end of the month.

Venus is still a morning star, but is gradually overtaking the Sun in its eastward motion, and the distance between the two is diminished from 31° to 23° during the month. The planet moves about 40° eastward from *Scorpio* through the southern extension of *Ophiuchus* to the eastern boundary of *Sagittarius*. It is in conjunction with *Uranus* on January 4th, passing $1^{\circ} 10'$ north, with *Jupiter* on January 15th, passing $0^{\circ} 22'$ north, and with *Saturn* on January 24th, passing $0^{\circ} 20'$ south. It then rises only $1^h 20^m$ before sunrise.

Mars is gradually approaching opposition, and is beginning to rise at a time suitable for observation before midnight. It moves about 1° eastward in the constellation *Leo* up to January 14th, and then begins to retrograde, moving about 2° westward before the end of the month. In retrograding it follows a path a little north of the one described while it was moving eastward. Its distance from the Earth diminishes from eighty-seven millions to sixty-eight millions of miles, and its brightness increases more than one half.

Jupiter, *Saturn*, and *Uranus* are all early-morning objects, and not one of them is well situated for observation. All three passed conjunction with the Sun in December. *Jupiter* rises long enough before sunrise to be easily seen; *Uranus* rises about an hour earlier than *Jupiter*, but cannot easily be made out on account of its faintness; *Saturn* is much nearer the Sun, and can probably not be seen with the naked eye until after the middle of the month.

Neptune is a little past opposition with the Sun, and is in good position for evening observation on the border of *Taurus* and *Gemini*, but it needs a telescope to bring it out.

FEBRUARY.

Mercury is an evening star throughout the month, and comes to greatest east elongation on the afternoon of February 19th, but the apparent distance of the planet from the Sun is much less than the average distance at greatest elongation, because the planet is in perihelion on the morning of the same day. It can probably be seen by the naked eye, when the weather conditions are favorable, for a week or two, but the conditions for visibility will be much more favorable during the following greatest east elongation, which is due in June.

Venus is still a morning star, but is even nearer the Sun than during January. By the end of the month it is about 14° west of the Sun, and it is also 7° south; so that the interval between the rising of the planet and sunrise is only about half an hour, and the planet will be hard to see.

Mars reaches the best position for observation it has given us since its last opposition, a little more than two years ago. It is in opposition with the Sun on the evening of February 21st. As compared with other oppositions, however, this is about the most unfavorable, since the planet comes to aphelion on February 24th, only three days from the time of opposition. Its distance from the earth will then be only a little less than sixty-three millions of miles, whereas during an August opposition the distance is nearly thirty millions of miles less. The brightness of the planet will be only about one fourth of its brightness at a favorable opposition. It will, however, be several times brighter than the first-magnitude star *Regulus*, which is near it. It is in the constellation *Leo*, and moves about 10° westward and southward during the month, and at the end is about 3° east and north of *Regulus*.

Jupiter, *Saturn*, and *Uranus* are still in the morning skies, but are farther away from the Sun, and rise nearly two hours earlier than during January. *Jupiter* and *Saturn* are both in *Sagittarius* and are moving eastward, *Jupiter* more than 5° , and *Saturn* about 3° ; so that at the end of the month they are less than 7° apart. This distance will still further diminish until the end of April, when the planets begin their retrograde motion. *Uranus* is higher up than *Jupiter* and *Saturn*, a little more than an hour's motion ahead of *Jupiter* and at about the same declination.

Neptune is in about the same position between *Taurus* and *Gemini*.

JANUARY-FEBRUARY, 1901.

PHASES OF THE MOON, P. S. T.

Full Moon	Jan. 4,	4 ^h 13 ^m	P. M.
Last Quarter	Jan. 12,	12 38	
New Moon	Jan. 20,	6 36	A. M.
First Quarter	Jan. 27,	1 52	
Full Moon	Feb. 3,	7 30	
Last Quarter	Feb. 11,	10 12	
New Moon	Feb. 18,	6 45	P. M.
First Quarter	Feb. 25,	10 38	A. M.

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Jan. 1,	18 ^h 45 ^m	— 23° 2'	7 ^h 27 ^m A. M.	12 ^h 4 ^m P. M.	4 ^h 41 ^m P. M.
11,	19 29	— 21 52	7 27	12 8	4 49
21,	20 12	— 19 59	7 22	12 11	5 0
31,	20 54	— 17 29	7 15	12 14	5 13
Feb. 10,	21 34	— 14 29	7 4	12 14	5 24
20,	22 13	— 11 3	6 52	12 14	5 36
Mar. 2,	22 51	— 7 21	6 37	12 12	5 47

MERCURY.

Jan. 1,	17 53	— 24 4	6 40 A. M.	11 12 A. M.	3 44 P. M.
11,	19 2	— 24 15	7 7	11 40	4 13
21,	20 12	— 22 5	7 31	12 12 P. M.	4 53
31,	21 23	— 17 21	7 44	12 43	5 42
Feb. 10,	22 30	— 10 20	7 46	1 10	6 34
20,	23 18	— 3 0	7 20	1 10	7 0
Mar. 2,	23 21	— 0 25	6 43	12 42	6 41

VENUS.

Jan. 1,	16 40	— 20 55	5 13 A. M.	9 58 A. M.	2 43 P. M.
11,	17 33	— 22 28	5 43	10 12	2 51
21,	18 27	— 22 55	5 50	10 27	3 4
31,	19 21	— 22 12	6 1	10 41	3 21
Feb. 10,	20 14	— 20 22	6 7	10 55	3 43
20,	21 6	— 17 33	6 8	11 7	4 6
Mar. 2,	21 55	— 13 54	6 5	11 17	4 29

MARS.

Jan. 1,	10 58	+ 10 9	9 42 P. M.	4 17 A. M.	10 52 A. M.
11,	11 1	+ 10 9	9 6	3 41	10 16
21,	11 0	+ 10 37	8 25	3 1	9 37
31,	10 54	+ 11 33	7 36	2 16	8 56
Feb. 10,	10 43	+ 12 51	6 41	1 26	8 11
20,	10 29	+ 14 17	5 44	12 33	7 22
Mar. 2,	10 14	+ 15 35	4 39	11 33	6 27

JUPITER.

Jan.	1,	17	43	—	23	5	6	24	A.M.	11	1	A.M.	3	38	P.M.
Feb.	1,	18	12	—	23	9	4	51			9	28		2	5
Mar.	1,	18	34	—	22	59	3	23			8	0		12	37

SATURN.

Jan.	1,	18	34	—	22	37	7	13	A.M.	11	52	A.M.	4	31	P.M.
Feb.	1,	18	49	—	22	24	5	26			10	5		2	44
Mar.	1,	19	0	—	22	10	3	47			8	27		1	7

URANUS.

Jan.	1,	16	52	—	22	31	5	31	A.M.	10	10	A.M.	2	49	P.M.
Feb.	1,	16	59	—	22	42	3	37			8	15		12	53
Mar.	1,	17	2	—	22	47	1	51			6	29		11	7 A.M.

NEPTUNE.

Jan.	1,	5	49	+	22	11	3	46	P.M.	11	6	P.M.	6	26	A.M.
Feb.	1,	5	46	+	22	11	1	40			9	0		4	20
Mar.	1,	5	45	+	22	11	11	49	A.M.	7	9			2	29

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

II, D, Jan.	13,	5 ^h	0 ^m	A.M.	II, D, Feb.	7,	1 ^h	59 ^m	A.M.
I, R,	16,	2	52		I, D,	8,	3	1	
III, D,	16,	6	23		II, D,	14,	4	33	
I, D,	23,	4	46		I, D,	15,	4	55	
I, D,	30,	6	39		III, D,	21,	2	12	
					III, R,	21,	4	45	
					I, D,	22,	6	49	
					I, D,	24,	1	18	
					I, D,	28,	6	10	

“AN ATLAS OF REPRESENTATIVE STELLAR SPECTRA.”*—A REVIEW.

By W. W. CAMPBELL.

This is the title of “PUBLICATIONS OF SIR WILLIAM HUGGINS'S OBSERVATORY, VOL. I.,” by Sir WILLIAM HUGGINS, K. C. B., and Lady HUGGINS, issued in March, 1900. Outwardly, the volume is a masterpiece of the bookmaker's art. It is doubtful if any other astronomical book of this century is so

* Published by WM. WESLEY & SON, London. £1 5s net.

truly an *édition de luxe*. In addition to thirteen half-sheet pages of celestial spectrograms, there are splendid photographic illustrations of the observatory and its instruments; and the charm of the book is greatly enhanced by some fifteen headpieces and initials exquisitely sketched by the pen of Lady HUGGINS. The pleasure of the reader is increased by these evidences that the beautiful in astronomy has not escaped the esthetic sense of the authors.

These external charms have their counterparts in the text. It is a record of pioneer work in stellar spectroscopy, written in sufficient detail to interest the technical astrophysicist, but in language so simple that the general reader can comprehend equally well.

Sir WILLIAM HUGGINS's observatory, founded in London in 1856, contained at first a five-inch Dolland telescope, which was replaced by an eight-inch Clark in 1858. His work was mainly in the line of physical observations of the planets. KIRCHHOFF's discovery of the significance of the Fraunhofer spectrum-lines in 1859 attracted HUGGINS's attention to the possibility of applying these newly discovered principles to the study of the stars. Inviting Dr. MILLER, Professor of Chemistry in King's College, to join him in the work, these gentlemen constructed a small spectroscope and attached it to the eight-inch refractor; and their great work of laying the foundations of the spectroscopic astronomy began at once. "The observatory became a meeting-place where terrestrial chemistry was brought into direct touch with celestial chemistry. The characteristic light-rays from terrestrial hydrogen shone side by side with the corresponding radiations from starry hydrogen, or else fell upon the dark lines due to the absorption of hydrogen in *Sirius* or in *Vega*. Iron from our mines was matched, light for dark, with stellar iron from opposite parts of the celestial sphere. Sodium, which upon the Earth is always present with us, was found to be widely diffused through the celestial spaces.

"The time was, indeed, one of strained expectation and of scientific exaltation for the astronomer, almost without parallel; for nearly every observation revealed a new fact, and almost every night's work was red-lettered by some discovery."

The preliminary results obtained by HUGGINS and MILLER, showing that the chemistry of the solar system prevails wherever the spectroscope was pointed, were communicated to the Royal

Society in 1862. It is a remarkable fact that on the day their paper was read the Society learned that similar observations had been made by RUTHERFORD in New York. A little later, the spectra of the stars were also studied by SECCHI in Italy, and by VOGEL in Germany.

Perhaps the most interesting observation of all was that made by HUGGINS in August, 1864, on the planetary nebula in *Draco*. It is hardly possible for the younger members of our profession to realize the profound interest taken in the discussion of questions concerning the nebulae. The increasing power and perfection of telescopes had enabled HERSCHEL and others to resolve one nebula after another into stars; and it was held by many that all nebulae were probably clusters of stars, which the powerful telescopes of the future would resolve. HERSCHEL himself was of the opinion that the very extended nebulosities, at least, were composed of matter self-luminous, "more fit to produce a star by its condensation, than to depend on the star for its existence."

HUGGINS's observation of the *Draco* nebula solved the problem. The spectrum was monochromatic. First, one bright line was visible; and later two others were detected. This nebula was "not an aggregation of stars, but a luminous gas." Of sixty nebulae and clusters examined, about one third gave the bright-line spectrum, indicating their gaseous nature.

The first observations of the spectrum of a "new star" were made by HUGGINS and MILLER in May, 1866.

About this time HUGGINS recognized the possibility of measuring the motion of a star in the line of sight, by means of the displacement of its spectrum; and a spectroscope for this purpose was constructed. While the enormous difficulties of the subject were not overcome, yet his ideas were opening up a field whose limits cannot even now be discerned.

HUGGINS's observations of a comet spectrum in 1868 led at once to the recognition of the important part played in comets by carbon; and his photograph of a comet spectrum in 1881 led to the detection of nitrogen radiations in these bodies.

His resources were greatly increased in 1870 by the loan, from the Royal Society, of a 15-inch Grubb refractor and an 18-inch speculum reflector.

It is interesting to note HUGGINS's courage in trying new methods: stellar spectrograms were attempted in 1863 with wet-plates; but these plates were impracticable, and their use had to

be given up. His photographic work began again in 1875-76, when rapid dry-plates were available. Many of the spectra on which he had worked visually were now studied photographically. His photographs have been taken largely with spectrographs provided with Iceland-spar prisms and quartz lenses. These materials transmit the radiations of short wave-lengths, and his spectra of the brighter stars extend far into the ultra-violet.

Sir WILLIAM HUGGINS's chief interest has been in reference to the evolution of the stars; and his photographs are discussed almost entirely from this point of view. His earlier observations on the visual portions of the spectra led him to arrange the brighter stars as to their age, or state of development, about as follows:—

Sirius.—Vega.

.....

α Aquilæ.

Rigel.

α Cygni.

.....

.....

Capella.—The Sun.

Arcturus.

Aldebaran.

Betelgeux.

His researches on the ultra-violet spectra of those stars confirm, in his opinion, the above order of arrangement. The discussion of this question is the chief technical interest of the volume. It is based on HELMHOLTZ's law that the mutual gravitation of the previously widely separated portions of a star is sufficient to account for the high temperature generated in it; on LANE's law that the temperature of a star will increase so long as the star is purely gaseous, after which the temperature will decrease; and on the generally accepted fact that as the temperature rises the maximum of the continuous spectrum shifts to the violet. HUGGINS's observations have led him to the somewhat unexpected conclusion that the true continuous spectrum is relatively stronger in the ultra violet of the metallic or solar type stars, such as *Procyon* or *Capella*, than in the white stars, *Sirius* or *Vega*. HUGGINS's photographs taken with spar and quartz optical trains are practically the only ones extant which bear strongly upon this important discovery. Confirmatory photo-

graphs, covering a large number of stars, are greatly to be desired. Granting HUGGINS's result to be indeed a fact, his stellar classification follows with comparative ease and certainty.

The authors describe, further, a series of experiments on the behavior of the calcium spectrum under varying conditions, and the results furnish further confirmation of their system of classification.

The book is referred to on the title page as Volume I. The appearance of subsequent volumes will be anticipated with interest.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DETERMINATION OF THE SUN'S DISTANCE, FROM OBSERVATIONS OF *EROS*.

The tendency of the times toward thorough organization and co-operation in large enterprises is well illustrated in modern astronomy. Thirty years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian-circle observations would combine to form the excellent *Astronomische Gesellschaft* star-catalogue; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris, some ten years ago.

About fifty of the principal observatories of the world are now co-operating in a great programme of observation for improving our knowledge of the distance between the Earth and Sun. Fully half the resources of the Lick Observatory have been devoted to this work for two months past, and the observations will continue one or two months longer.

The determination of the value of this astronomical unit of distance is one of the most famous problems in the science, and a great variety of methods has been used. Perhaps the best determination is that made by Sir DAVID GILL of the Cape of Good Hope, from heliometer observations of the nearer asteroids. The four hundred small planets (asteroids) discovered up to 1898 all move in orbits situated entirely outside the orbit of *Mars*. The observations of *Victoria*, *Iris*, and *Sappho*, which approach nearer to the Earth than any of the other members of the asteroid group, led to the result that the average distance from the Earth to the Sun is about 92,900,000 miles. The unavoidable errors to which all such observations are subject leave an

* Lick Astronomical Department of the University of California.

uncertainty of some 150,000 miles in this value: it may be too large or too small by this amount.

The accuracy of results obtained in this manner depends upon the distance of the observed body from the Earth, and upon its definiteness as a point of observation. *Mars* possesses the advantage of being nearer the Earth than the asteroids, but this advantage is greatly outweighed by the fact that an asteroid-point can be observed much more accurately than a large planet-disk. GILL's splendid work left much to be desired, but there

was no prospect that his value of the unit could be improved with instruments now available.

An asteroid discovered by Dr. WITT in Berlin, in 1898, to which he gave the name *Eros*, is very remarkable in that its orbit lies partly within and partly without the orbit of *Mars*. It approaches the Earth more closely than any other member of our system, except the Moon. The forms and relative positions of the orbits of the Earth, *Eros*, and *Mars* are shown approximately

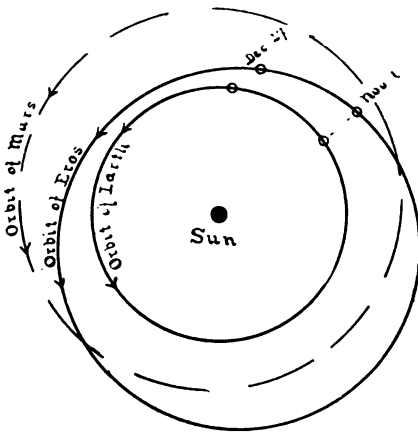


Fig. 1

by the accompanying diagram (Fig. 1). The orbits of *Mars* and *Eros* appear to intersect; but this is merely apparent, from the projection of the two on the plane of the paper. The plane of the orbit of *Eros* makes an angle of about eleven degrees with the plane of the orbit of *Mars* (and the Earth), and the two orbits are situated like two adjacent links of a chain without approaching each other very closely.

As soon as the orbit of this wonderfully-located asteroid was computed and published, astronomers realized its possibilities for improving our knowledge of the Sun's distance. As stated above, an asteroid's value for this purpose depends upon its closeness to the Earth. The distance of *Eros* at this opposition will have a minimum value of 27,000,000 miles. Unfor-

tunately, the more favorable opposition of 1896, when the distance diminished to 15,000,000 miles, was not available, as the planet remained undiscovered; and an equally good opposition will not occur again for a quarter of a century.

In outline, this method of measuring the Sun's distance is exceedingly simple; but in detail it is exceedingly complex and technical. The nature of the problem may be explained from Fig. 2.

If the Earth is at E and the asteroid at A, an observer on the Earth's surface at P will see the asteroid projected on the sky at P', whereas an observer at L will see it at L'. If the distance PL is known, as it is, and the angle PAL is obtained from the observations, the data for solving the triangle PLA are at hand,

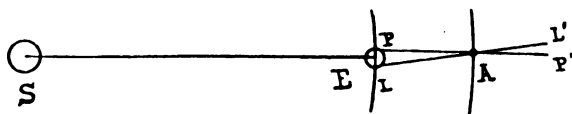


Fig. 2

and the distance EA may be obtained by simple computation. As a second step in the solution, the orbit of *Eros* will be determined very accurately, basing the determination upon NEWTON'S law of gravitation. It will then be a simple matter to compute the ratio of the Earth's distances from the Sun (ES) and the asteroid (EA). The distance EA having already been determined in miles, the desired distance ES will follow.

If two observatories on opposite sides of the Earth secure observations simultaneously, say at P (Pulkowa, in Russia) and at L (Mt. Hamilton), the desired data are theoretically complete; but practically they are insufficient. There are unavoidable errors in the measurement of the very small angle PAL, and in the assumed positions of the two observatories, which will be materially reduced by having observations made at a large number of stations. The direct distance between the Pulkowa and Lick Observatories is about 5,000 miles. This is a base-line from which to measure a distance of 27,000,000 miles, and thence the three-and-one-half-fold greater distance to the Sun. The form and the dimensions of the Earth thus enter directly into the problem. An error of a quarter of a mile in the assumed length of the base-line leads to a large error in the final result.

Instead of simultaneous observations made in the morning in Russia and in the evening in America, the angle PAL can be

determined by evening and morning measures secured at one station.

The July conference of astronomers at the Paris Exposition afforded an opportunity for a hurried formation of co-operative plans to secure the observations needed. It may be said that every one of the contributing observatories is devoting to this problem all of its resources which in any way promise to improve the results. The measures are most advantageously made in November and December; and perhaps a hundred observers are giving their time to this work. The reductions will require one or two years' labor, and the value of the Sun's distance, resulting from a combination of all the work of all the observatories will probably not be available for two or three years.

The Lick Observatory is contributing as follows:—

Astronomer R. H. TUCKER, assisted by Mr. CRAWFORD, is securing two meridian-circle observations of each of 700 stars, to determine their positions with the utmost accuracy. These positions, furnished by perhaps a dozen or more observers, will form the triangulation system, or groundwork, upon which the whole structure of the determination will be based.

Astronomer W. J. HUSSEY and Assistant Astronomer R. G. AITKEN, with the assistance of Mr. WRIGHT and Dr. REESE, are using the great telescope five or six nights per week, weather permitting, to measure the evening and morning positions of *Eros* with reference to the fixed stars in the asteroid's vicinity. The positions of these reference-stars will be secured by means of photographs of the regions taken with eight or ten telescopes, mostly in Europe.

Assistant Astronomer C. D. PERRINE, assisted by Mr. PALMER, is employing the Crossley reflector every clear night to obtain photographs of *Eros* and its surrounding stars, to furnish the planet's accurate position in the evening, in the morning, and on the meridian. The measurement of these plates will be a heavy task. Fortunately, Professor REES, Director of the Columbia University Observatory, has volunteered to measure them. Columbia University is the only institution in this country which has had experience in measuring such plates, though many foreign observatories have long been doing similar work.

The planet *Eros* is now of about the 9.3 magnitude. It is easily visible in a three-inch telescope. W. W. CAMPBELL.

LICK OBSERVATORY, November 24, 1900.

OBSERVATIONS OF THE BINARY STARS δ EQUULEI (= O Σ 535,) AND κ PEGASI (= β 989,) IN 1900.

In carrying out my programme of observing the more interesting and difficult binary stars annually, I turned the 36 inch telescope upon κ Pegasi on the night of July 22, 1900, and secured a measure without particular difficulty, though the distance between the two components was only 0".17. Turning next to δ Equulei, which is a very similar pair in point of magnitude, I was unable to make a measure. This was a great surprise to me ; for a year ago it was much easier to measure than κ Pegasi, and my recollection of the generally accepted orbit did not lead me to expect so rapid a diminution in the distance.

On the night of August 10th, with rather poorer conditions, I again failed on δ Equulei, and turning directly afterward to κ Pegasi secured a satisfactory measure. On the following night, Saturday, August 11th, the seeing was excellent, and I was able to detect a slight, but certainly real elongation of δ Equulei, regarding which my observing note says "the distance (between the two components) is not greater than the thickness of the micrometer-wire,"—i. e., less than one tenth of a second of arc. Perhaps the best estimate of the observing conditions on this night may be formed from the fact that in little over five hours I secured measures of eighteen pairs of double stars, ten of which had distances of less than 0".25 and only three, distances greater than 0".50. Having measured a pair with a distance of 0".15 shortly before turning to δ Equulei, and κ Pegasi (distance 0".17) immediately afterward, I am confident that the observing note just quoted states the distance correctly.

After failing again, on September 8th, to see any elongation in this star, though the seeing was good enough to make possible the measures of seven other pairs at an average distance of 0".30, I called the attention of Professor HUSSEY, who is specially interested in the OTTO STRUVE double stars at present, to δ Equulei. For it was obvious that the existing orbits needed radical modifications to account for so small a separation between the two components at the present time. According to Dr. SEE's revised orbit, the latest one published, the distance has been diminishing during the past two years, but at the date, 1900.85 (about November 7th) it should still be 0".28, an easily measurable quantity with the 36-inch refractor on any good night.

In the past two months I have examined δ *Equulei* on four nights when the seeing was good enough to measure very close stars. Three times I suspected elongation; once I failed completely. Settings were made on the suspected elongations, but were marked "uncertain," — particularly the last two — and the resulting angles differed so greatly that they seemed more than ever doubtful.

The short period elements, however, which Professor HUSSEY has recently completed (see p. 215 of this number), without reference to any of these observations, except the one on August 11th, indicate that in all probability the elongations noted were real; for, according to these elements, the distance during the past few months has been considerably less than $0''.10$, and therefore a residual in angle of even 28° means a displacement of the micrometer-wire of only one third of its own thickness.

In view of the very interesting result obtained by Professor HUSSEY in his study of the orbit of this star, it has seemed desirable to make this detailed record of my observations. The tabular statement is as follows: —

Date.	Position-Angle.	Distance.	Eye-piece.	Seeing.
1900 557	 Failed to measure		1900	3
.609	 Failed to measure		1500	3
.612	 $137^\circ.8$ ($317^\circ.8$)... | $<0''.10$		2600	4+
.688	 No elongation seen		1900	3
.746	Elongat'n suspect'd in $107^\circ.2$ | $<0''.10$		2600	4
.787	Two micrometer settings gave an angle of $95^\circ.3$. My observing note says: "Settings quite uncertain, but star certainly elongated in general preceding-following direction."		1900	3
.836	 No elongation seen		1900	3
.858	One "very uncertain" setting gives an angle of 84°		1900	3

The measures of κ *Pegasi* are as follows: —

1900.557	$272^\circ.8$	$0''.17$	1500	3
.576	$267^\circ.2$	$0''.17$	1500	3
.609	$266^\circ.1$	$0''.18$	1500	3
.612	$265^\circ.0$	$0''.17$	1900	4+
1900.59	$267^\circ.8$	$0''.17$		

According to BURNHAM's elements for this pair, the position in 1900.59 was $263^{\circ}.5$ and $0''.16$, leaving residuals for the above observations of $(O - C) + 4^{\circ}.3$ and $+ 0''.01$. As the smaller star has moved over an arc of 220° since these elements were computed, such an agreement between prediction and observation indicates that BURNHAM's orbit is very exact.

November 16, 1900.

R. G. AITKEN.

LEONIDS IN 1900.

About a week previous to November 15th, a number of meteors were seen which appeared to come from the *Leonid* radiant. All were seen well toward the western horizon, and had the characteristics of the *Leonids*. No especial watch was kept for them then. On the morning of Thursday, November 15th, meteors were counted from $15^h 15^m$ to $15^h 55^m$. During this time nine were seen, of which eight were *Leonids*. None were of unusual brilliancy. Attention was directed more to the western sky on account of greater cloudiness to the east. Clouds at all times covered considerable portions of the sky so that probably not more than half as many meteors were observed as would have been visible in an entirely clear sky. A severe storm (still in progress) has prevented further observations.

MT. HAMILTON, November 21, 1900.

C. D. P.

OBSERVATIONS OF LEONID METEORS.

Six meteors coming approximately from the position of the Sickle in *Leonis* were observed this (Thursday) morning between half-past three and four o'clock P. S. T. The sky was cloudy throughout the morning, during the interval of observation from three tenths to five tenths being covered. Most of the meteors were faint, and were observed in the western sky, this being the part most free from clouds. No other meteors were seen.

November 15, 1900.

W. H. W.

OBSERVATIONS OF LEONIDS ON THE MORNING OF NOVEMBER 15TH.

In making these observations no attempt was made to record the separate paths of the meteors, all meteors emanating from the constellation *Leo* being counted together. The observations extended from 2:55 to 4:30 A. M., being taken during alternate intervals of five minutes throughout this time. Ten *Leonids* in

all were counted. During all this time there were light clouds in the neighborhood of *Leo*, and for about twenty minutes clouds and fog were so thick that only the brighter stars in the constellation were visible. After 4:30 the clouds thickened so much that the meteors were no longer watched for. The part of the sky covered by the observer included about fifty degrees on all sides of the radiant.

H. M. R.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Dr. HENRY S. PRITCHETT, for some years Professor of Astronomy in Washington University, St. Louis, and recently Superintendent of the United States Coast and Geodetic Survey, was inaugurated President of the Massachusetts Institute of Technology on October 24th.

The degree of Doctor of Science has been given by Cambridge University to Professor S. P. LANGLEY, Director of the Smithsonian Institution.

Dr. HERMAN S. DAVIS, recently expert computer of the United States Coast and Geodetic Survey, has been appointed observer at the International Latitude Observatory at Gaithersburg, Maryland, one of the six stations established by the Central Bureau der Internationalen Erdmessung for an investigation of variations of latitude.—*Science*, November 9, 1900.

The will of Professor PIAZZI SMYTH makes provision for the publication of his spectroscopic manuscripts, and also for the assistance or promotion every ten or twenty years of an expedition for the study of some particular branch of astronomical spectroscopy at mountain elevations of not less than 6,000 feet.

Nature for October 25th contains an interesting article under the title, "Recent and Proposed Geodetic Measurements." From it we learn that the French propose to remeasure the Peruvian arc measured by BOUGNER in 1735-45. A preliminary survey of the region has been made, and it has been decided to extend the arc at both ends so that it will cover six degrees of latitude, about twice the extent of the former measurement. The arc will cross the equator extending from the neighborhood of Sullana in Peru to Pasto in Columbia. The country is far from smooth, and the task will be a difficult one. "Three bases of about eight or nine kilometers in length will be measured, one approximately central and two of verification at the north and south ends respectively. The difference of level between the central base and the sea at Guayaquil, where tide-gauges will be erected, will be determined with the greatest nicety. Throughout the arc fifty-two stations will be selected for observation, of which

three will be fundamental, and the longitudes be determined by telegraph. Magnetic observations will be carried on as a matter of course, and in a country marked by so many mountain masses special care will be taken to determine their extent and density, with the view of eliminating the effect of local attraction." The work of this survey will be commenced next spring.

The Russian and Swedish governments are carrying out the measurement of an arc in the extreme north, in Spitzbergen, between latitudes seventy-seven and eighty-one degrees. Two base lines will be measured and fifty triangulation stations occupied. The work is already well under way.

A third arc is now being measured in South Africa, and if the director of the work, Sir DAVID GILL, Her Majesty's Astronomer at the Cape of Good Hope, is able to carry out his plans, this will dwarf into insignificance anything heretofore done in the way of measuring an arc of a meridian. He proposes to extend the measurements from the Cape of Good Hope to the mouth of the Nile, and thence across the Mediterranean Sea by means of the islands of Greece, and there to connect with the European systems, making in all an arc 105° in extent. It is to be hoped that the plan can be successfully carried out, but the difficulties are many. A start upon the work has already been made, but measurements are temporarily at a standstill on account of the war with the Boers.

The November number of *Popular Astronomy* contains an interesting account of the opening of the Whitin Observatory of Wellesley College. The building, of white marble, was built and equipped by one of the trustees of the College, Mrs. JOHN C. WHITIN. "The initial equipment consists of a 12-inch Clark equatorial refractor, a 3-inch transit, a sidereal clock, chronograph and a 6-foot-focus Rowland concave-grating spectroscope with heliostat. The telescope is furnished with spectroscope for solar work, polarizing photometer, micrometer, and small star spectroscope, all with electric illumination. Other minor instruments are already purchased, and it is intended to provide less costly apparatus in duplicate for the elementary practice of laboratory divisions."

Two addresses were given on the occasion, one by Professor EDWARD C. PICKERING, of Harvard, on "The New Planet *Eros*," the other by Professor DAVID P. TODD, of Amherst, on "Laboratory Work in Astronomy."

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 24,
1900, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED NOVEMBER 24, 1900.

Mr. A. D. AUSTIN	{	Carlton Terrace, Christchurch, New Zealand.
Mr. PAUL M. BRNEDICT	{	Care of Thos. H. Pease & Son, 102 Church St., New Haven, Conn.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE
CALIFORNIA ACADEMY OF SCIENCES, NOVEMBER 24,
1900, AT 8 O'CLOCK P. M.

Mr. PIERSON presided. The minutes of the last meeting were approved.

The following papers were presented:—

1. On the Progress made in the Last Decade in Determination of Stellar Motions in the Line of Sight, by H. C. VOGEL. (Reprinted from *Astrophysical Journal*)
2. Planetary Phenomena for January and February, 1901, by MALCOLM MCNEILL.
3. The Orbit of *99 Herculis*, by R. G. AITKEN.

Mr. PIERSON opened the meeting with an account of the life of Professor KEELER, late President of the Society, and read the resolutions adopted expressing the sorrow felt by the members at his untimely death.

He then introduced the lecturer of the evening, explaining the importance to science of the new method of photographing the Corona, and read a number of letters from the most eminent astronomers, expressing in the highest terms their gratification at the successful results obtained.

Mr. BURCKHALTER gave an account of his expedition to Siloam, illustrated by lantern slides of the eclipse station and of the photographs of the Corona, and explained, by means of drawings and models of his apparatus, the method by which the exposure of the plates is controlled.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. JAMES E. KEELER*	President
Mr. CHARLES BURCKHALTER	First Vice-President
Miss R. O'HALLORAN,	Second Vice-President
Mr. S. D. TOWNLEY	Third Vice-President
Mr. C. D. PERRINE }	Secretaries
Mr. F. R. ZIEL }	
Mr. F. R. ZIEL	Treasurer

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Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.

Library Committee—Mr. TOWNLEY, Miss O'HALLORAN, Miss HOBE.

Committee on the Comet-Medal—Messrs. KEELER* (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



* Deceased.

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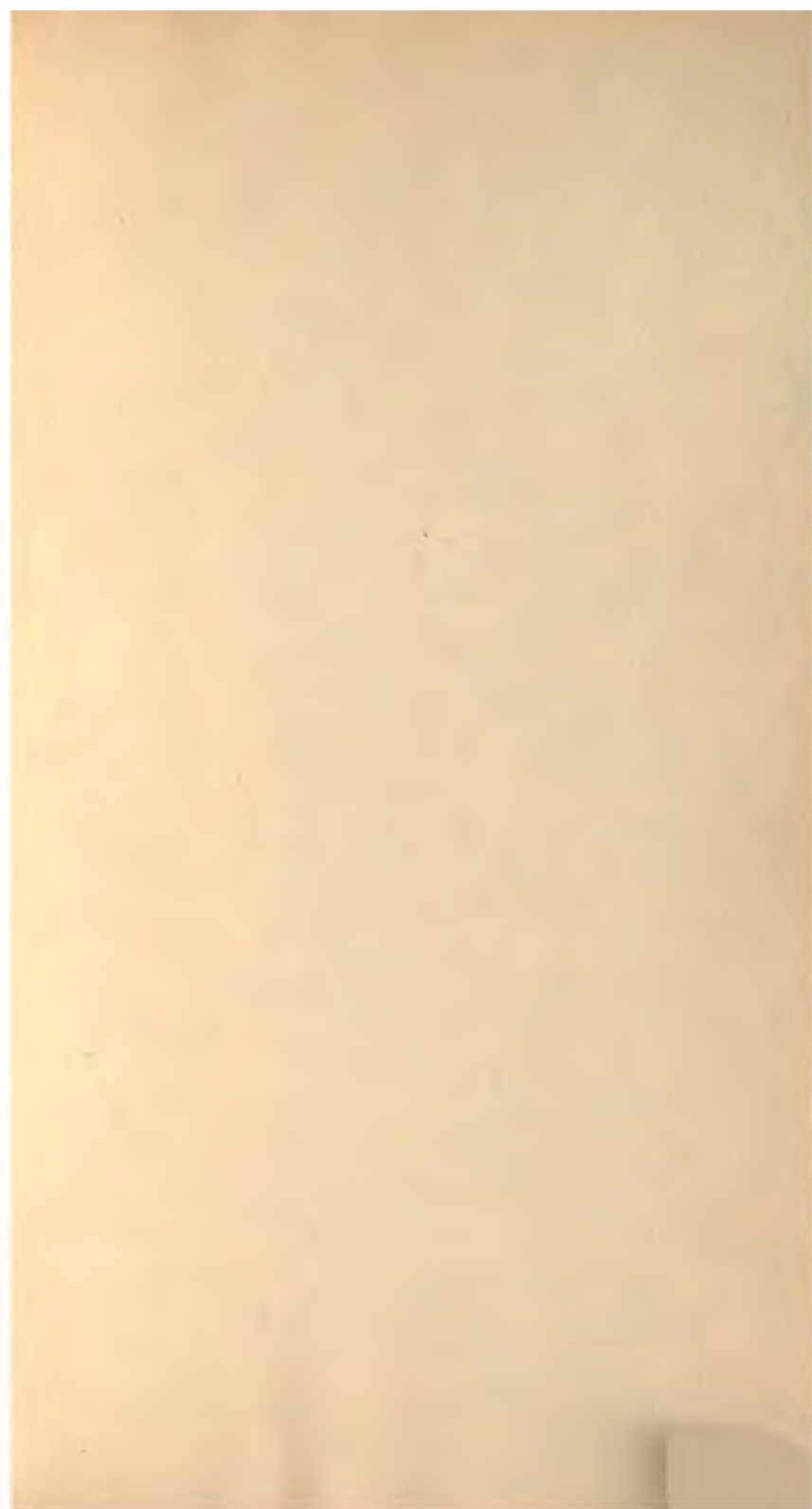
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